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Adaptivní vícekanálová přístupová bezdrátová komunikační architektura pro dopravní systémy

Adaptive multi-path wireless access communication architecture for transport systems

Summary:

Wide range of available and forthcoming transport telematic services leads to their integration in one vehicle OBU (On Board Unit). This approach called “One OBU on board” represents great challenge. However, it requires the system support of the whole portfolio of telecommunications services. Access solutions switching is subject of intensive R&D and this area is also covered by the ISO/CEN CALM standards initiative. These standards are focused namely on system architecture and switching tools. Decision schemes do not have high priority and the widely applied Policy-based Management (PBM) is mostly accepted as the appropriate approach. The proposed alternative of adaptive decision processes is based on the self trained classification. Time line of the measured data with its correct assignment to the relevant class/path represents training data. Decision processes can be continuously improved in their quality if the self training processes continue in the application period.

2.5G GSM data services package and (Mobile) WiMax (IEEE 802.16d/e) wireless access system has been identified as appropriate combination applicable for remarkable range of telematic solutions. Additionally, automotive CAN bus, DSRC and minimally one representative of PAN solutions should be included in the OBU telecommunications services portfolio. The presented system solution is equipped with all above mentioned telecommunications solutions.

General multi-path access telecommunications solution defined by family of CALM standards accepts transparent matrix architecture which corresponds to the principles applied in “carrier grade” telecommunications system design. Current trend in chip sets and modules R&D and production does not mostly meet professional telecommunications solutions requirements, as they follow the mass market terminals needs. The area of mass market terminal has in comparison to the “carrier grade” solutions significantly more “liberal” approach to the system architecture. Until OBU is massively installed in all vehicles, which will significantly influence the OBU production volumes, conditions of unit designs will remain unchanged. Therefore it will be necessary to invent the compromise approach of the OBU designers which will have to take in account rules generated by the mass market terminals dominance.

Shrnutí:

Široké spektrum dostupných stejně jako připravovaných telematických služeb vede k integraci služeb do jedné palubní vozidlové jednotky (OBU). Tento přístup je velkou výzvou vyžadující ale koncentraci celého použitelného portfolia telekomunikačních služeb. Řešení na bázi přepínání vícekanálového přístupového řešení je úzce spojeno s přípravou ISO/CEN standardů CALM. Tyto standardy řeší především systémovou architekturu a vlastní nástroje přepínání, ale procesy výběru nejvhodnější alternativy již nedostaly odpovídající prioritu a v IP sítích běžně užívaný PBM (Policy-based Management) přístup je většinou vnímán jako přiměřené řešení. Navrhovaná alternativa rozhodovacích procesů vychází z principů samoučících se klasifikačních procesů. Trénovacími daty jsou časové řady již naměřených parametrů doplněné o správný výběr komunikačního řešení. Pokud samoučící se procesy pokračují i v aplikační periodě, lze tím dosáhnout postupného zkvalitňování identifikačních procesů.
Kombinace portfolia datových služeb 2,5-té generace GSM se službami WiMax (IEEE 802.16d/e) byla identifikována jako vhodné řešení pro pokrytí požadavků širokého spektra dopravních telematických služeb. OBU jednotka musí dále podporovat automobilní CAN sběrnici, systém DSRC a minimálně jednoho z reprezentantů PAN technologií. Předložená systémová architektura je vybavena moduly podporujícími všechna výše zmíněná telekomunikační řešení.
Obecná více-kanálová přístupová telekomunikační řešení definovaná standardy CALM akceptuje transparentní maticovou architekturu, která koresponduje s principy z oblasti profesionálních telekomunikačních systémů. Současný výzkum, vývoj a výroba setů integrovaných obvodů se neubírají tímto směrem, ale jsou především orientovány na oblast koncových zařízení masového trhu. Tato oblast ve srovnání s profesionálními telekomunikačními systémy má výrazně „liberálnější“ přístup k transparentnosti systémové architektury. Do té doby, než bude jednotka OBU masově instalována do každého vozidla s důsledkem zásadního nárůstu objemu výroby OBU jednotek, nelze očekávat, že se situace zásadně změní. Proto je pro toto období nutné hledat kompromisní řešení návrhu OBU jednotek s nezbytností i využití přístupů a prvků vyplývající z dominance řešení terminálů masové spotřeby.

Klíčová slova: inteligentní dopravní systémy, dopravní telematika, performační indikátory, telekomunikace, bezeztrátové přepínání, bezdrátové přístupové telekomunikační řešení, CALM, rozhodovací procesy

Key words: intelligent transport system, transport telematics, performance indicators, telecommunications, seamless switching, wireless telecommunications access solutions, CALM, decision processes

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1 INTRODUCTION

The area of the Intelligent Transport systems (ITS) is associated with serious society expectations and getting ITS applications in the real practice is understood as the essential potential to significantly faster resolve many transport problems. The ITS architecture reflects several different views of the examined system and can be divided into:

- Reference architecture - defines the main terminators of ITS system (the reference architecture yields to definition of boundary between ITS system and environment of ITS system),
- Functional architecture - defines the structure and hierarchy of ITS functions (the functional architecture yields to the definition of functionality of whole ITS system),
- Information architecture - defines information links between functions and terminators (the goal of information architecture is to provide the cohesion between different functions),
- Physical architecture - defines the physical subsystems and modules (the physical architecture could be adopted according to the user requirements, e.g. legislative rules, organization structure, etc.),
- Communication architecture - defines the telecommunications services between physical devices (correctly selects set of telecommunications service),
- Organization architecture - specifies competencies of single management levels (correctly selected organization architecture optimizes management and competencies at all management levels).

ITS implementations usually cover widely spread areas and quality of provided services is considerably dependent on guarantied quality of the applied set of telecommunications services. Author of this paper concentrates his effort on telecommunications support of the ITS solutions structured as follows:

- Identification of the ITS system performance requirements impact on the telecommunications solution parameters (performance indicators),
- Architecture of multi-path wireless access telecommunications structures,
- Detailed analysis of the external as well as internal performance indicators of each accepted wireless telecommunications solution,

- Decisions processes implementation into the multi-path wireless telecommunications system management.

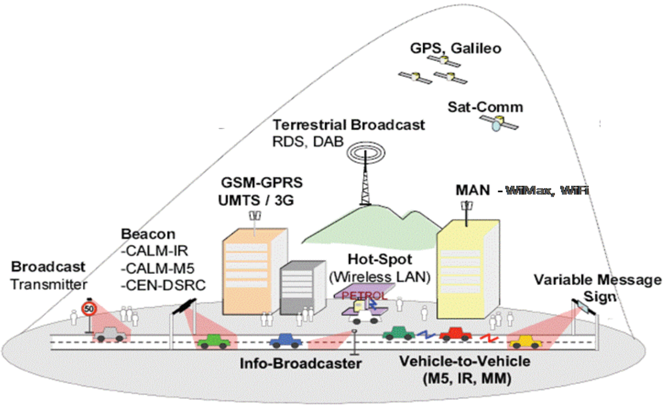

Fig. 1. Transport telematics telecommunications access solutions

Fig. 1 (see [11]) has been cited all around the world in order to explain complexity of the both ITS structures and relevant telecommunications solutions. This figure also points out remarkable challenge based on fact that the wide range of different requirements of different telematic services is reachable only if available telecommunications services are effectively combined. The sophisticated integration of the whole range of potentially available telecommunications services opens possibility for the compact ITS solution supported by one On Board Unit (OBU). “One OBU on the vehicle board” strategy is challenging opportunity with very good potential for successful implementation of complex ITS services packages in wide variety of both personal as well as professional vehicles.

2 TELECOMMUNICATIONS SOLUTION

2.1 Telematic sub-system requirements

The first step in addressing the ITS architecture requirements is the analysis and establishment of performance parameters in designed telematics applications, in co-operation with the end-users or with organizations like Railways Authority, Road and Motorways Directorates, Airport and Air-transport Authorities, etc. The methodology for the definition and measurement of following individual system parameters – performance indicators - was developed in frame of the ITS architecture (see [1] - [5]):

- *Availability* - the ability to perform required function at the initialization of the required operation.
- *Integrity* - the ability to provide timely and valid alerts to the user when a system must not be used for the intended operation.
- *Continuity* - the ability to perform required function without non-scheduled interruption during the intended operation.
- *Accuracy* - the degree of conformance between a platform's true parameter and its estimated value, etc.
- *Safety* - risk analysis, risk classification, risk tolerability matrix, etc.
- *Reliability* - the ability to perform required function under given conditions for a given time interval.

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 with goal 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, optimal use of the existing information and telecommunications infrastructure, etc.). It is obvious that quantification of the requirements on relevant telecommunications solutions within telematic chains plays one of the key roles in this process.

The mobility of the telecommunications solution represents one of the key system properties namely in context of frequently specific demands on the availability and security of the solution. Monitoring and management of the airport over-ground traffic was one of our key projects. This area has been very strictly, nevertheless, transparently regulated. Successful results of the ITS system tests processed under complex airport conditions can be understood as the representative telematic reference.

Data transmission capacity can act due to possible high density of moving objects and limited wireless capacities critical system requirements, which can be resolved either by application of broadcasting regime of data distribution or by selective individually reduced frequency of positional data distribution. Distance between objects or moving objects density in area represent simple but effective criteria for such individual data distribution management.

Following telecommunications performance indicators quantify telecommunications service quality (see e.g. [6] - [10]):

- *Availability* –
  - Service Activation Time,
  - Mean Time to Restore (MTTR),
  - Mean Time Between Failure (MTBF),
  - VC availability,
- *Delay* is an accumulative parameter effected by
  - interfaces rates,
  - frame size,
  - load / congestion of all in line active nodes (switches),
- *Packet/Frames Loss*,
- *Security*.

2.2 Telecommunications design methodology

The performance indicators described for telecommunications applications must be transformed into the telematic performance indicators structure, and vice versa. Such transformation allows system synthesis. Final additive impact of the vector of telecommunications performance indicators $\overrightarrow{tci}$ on the vector of telematic performance indicators $\overrightarrow{tmi}$ can be expressed by Eq. 1, however, only under condition that probability levels of all indicators are set on the same level and all performance indicators are expressed exclusively by time value. We can express that

$$\Delta\overrightarrow{tmi} = TM \cdot \overrightarrow{tci}, \qquad (1)$$

where $\Delta\overrightarrow{tmi}$ represents the additive impact of $\overrightarrow{tci}$ on $\overrightarrow{tmi}$ and *TM* is transformation matrix. The identification of the *TM* represents iterative process and it can be handled in four iterative steps. The identification process starts with matrix in as general as possible structure TM_0. The transformation matrix TM_0 takes in account all potential relations between telecommunications and the telematic indicators. Matrix construction is dependent on the detailed telecommunications solution and its integration into telematic system. The probability of each phenomena appearance in context of other processes is not deeply evaluated in period the TM_0 identification.

In case of the CaMNA[1] final telecommunications solution $\Delta\overrightarrow{tmi}$ vector consists of

- Accuracy Δp_i,
- Availability $\Delta t_{ds,i}$,
- Reliability $\Delta t_{tna,i}$,
- Continuity Δt_i,
- Integrity $\Delta t_{tsna,i}$.

and vector $\overrightarrow{tci}$ consists of

- time to upload $d_{u,i}$,
- time to download $d_{d,i}$,
- handover within the same media $rc_{hs,m,i}$,
- handover within different (CALM) media $rc_{hd,m,i}$,
- feedback parameters settings period $rc_{r,m,i}$,
- MTTR of the terrestrial network service $rc_{r,f,i}$,
- MTTR of the access mobile service $rc_{rp,m,i}$,
- time period fix service is not available (self-healing not available or not successful) $t_{na,f,i}$,
- time period mobile service is not available (self-healing process not successful) $t_{na,m,i}$,
- time to accept OBU into relevant cell $t_{oi,i}$.

General impact of listed set of telecommunications performance indicators on above defined set of telematic performance indicators is described by Eq. 2 – 6:

$$\Delta p_i = v_i * \begin{pmatrix} d_{u,i} + \mathrm{r}c_{hs,m,i} + rc_{hd,m,i} + rc_{rp,m,i} + \\ + rc_{r,f,i} + rc_{r,m,i} + d_{d,i} + t_{na,m,i} + t_{na,f,i} \end{pmatrix}, \qquad (2)$$

$$\Delta t_{ds,i} = t_{oi,i} + d_{d,i} + \mathrm{r}c_{hs,m,i} + rc_{hd,m,i} + rc_{rp,m,i} + \\ + rc_{r,f,i} + rc_{r,m,i} + d_{u,i} + t_{na,f,i} + t_{na,m,i}, \qquad (3)$$

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

$$\Delta t_{tna,i} = t_{na,f,i} + t_{na,m,i} + ns_{hsm,i} * \mathrm{r}c_{hs,m,i} + \\ + ns_{hdm,i} * rc_{hd,m,i} + ns_{rpm,i} * rc_{rp,m,i} + \\ + ns_{sf,i} * rc_{r,f,i} + ns_{rm,i} * rc_{r,m,i}, \tag{4}$$

$$\Delta t_i = rc_{hs,m,i} + rc_{hd,m,i} + rc_{rp,m,i} + \\ + rc_{r,f,i} + rc_{r,m,i} + t_{na,m,i}, \tag{5}$$

$$\Delta t_{tsna,i} = rc_{hs,m,i} + rc_{hd,m,i} + rc_{rp,m,i} + \\ + rc_{r,f,i} + rc_{r,m,i} + d_{d,i} + t_{na,f,i} + t_{na,m,i}. \tag{6}$$

The transformation matrix structure *TM* of Eq. 1 in its initial stage before processing, i.e. TM_0, is described by:

$$TM_0 = \begin{bmatrix} k_{p,u,i} \cdot v_i, & k_{p,d,i} \cdot v_i, & k_{p,hs,m,i} \cdot v_i, & k_{p,hd,m,i} \cdot v_i, & k_{p,rp,m,i} \cdot v_i, & k_{p,r,f,i} \cdot v_i, & k_{p,r,m,i} \cdot v_i, & k_{p,na,f,i} \cdot v_i & k_{p,na,m,i} \cdot v_i & 0 \\ k_{d,u,i}, & k_{d,d,i}, & k_{d,hs,m,i}, & k_{d,hd,m,i}, & k_{d,rp,m,i}, & k_{d,r,f,i}, & k_{d,r,m,i}, & k_{d,na,f,i}, & k_{d,na,m,i}, & k_{d,oi,i} \\ k_{s,u,i}, & k_{s,d,i}, & k_{s,hs,m,i} \cdot ns_{hs,m,i}, & k_{s,hd,m,i} \cdot ns_{hd,m,i}, & k_{s,rp,m,i} \cdot ns_{rp,m,i}, & k_{s,r,f,i}, & k_{s,r,m,i}, & k_{s,na,f,i}, & k_{s,na,m,i}, & 0 \\ 0 & 0 & k_{k,hs,m,i}, & k_{k,hd,m,i}, & k_{k,rp,m,i}, & k_{k,r,f,i}, & k_{k,r,m,i}, & k_{k,na,f,i}, & k_{k,na,m,i}, & 0 \\ k_{i,u,i}, & k_{i,d,i}, & k_{i,hs,m,i}, & k_{i,hd,m,i}, & k_{i,rp,m,i}, & k_{i,r,f,i}, & k_{i,r,m,i}, & k_{i,na,f,i}, & k_{i,na,m,i}, & 0 \end{bmatrix}$$

where v_i is vehicle velocity $ns_{hs/hd/rp,m,i}$ represents number of appropriate phenomenon appearance (on agreed probability level) in time interval $\langle 0, T \rangle$. Value of each parameter $k_{xx,yy,m/f/-,i}$ is identified as either „0“ or „1“ in accordance to iterative process described below.

Each element of the transformation matrix *TM* is consecutively evaluated. The detailed analysis of the particular telematic and telecommunications configuration as well as probability of studied phenomenon appearance in context of the whole system performance must be taken in account. Such approach represents the iterative process managed with the goal to reach stage where all minor indicators (relations) are eliminated and the major indicators are identified with goal that relevant telematic performance indicators are kept in given tolerance range. Four steps of the process leading to the final stage are:

- [I] primary elimination of the telecommunications parameter based on implementation of relevant telecommunications solution or setting (e.g. guaranteed homogenous radio signal coverage in defined area – e.g. airport runway),
- [II] primary disregarding of telecommunications indicator, if its weight can be justified as insignificant,
- [III] identification and exclusion of indicators with significantly lower level of their appearance probability (e.g. in case of coincidence of processes with unified probability level of their individual occurrence - the dominant one is appointed),

[IV] conclusion of the iterative identification of the dominant indicators as the last step of the iterative process of the *TM* identification is based on the virtual telecommunications parameters settings. The potential solution modification can, however, lead identification process back to step [I].

The presented method is designed as universal as it is possible with clear aim to allow this method to be applied in the widest range of telematic application. This method can be also successfully applied for the CALM criteria identification. However, correct results of described iterative process are obtained only if the detailed knowledge of the studied system solution is available as well as all causal relations are identified and they are correctly taken in account.

2.3 Telecommunications solution structure

Fig. 2 presents the typical telecommunications solution architecture originally applied firstly in the pilot project CAMNA and Fig. 3 presents the chain diagram of the solution described on Fig. 2.

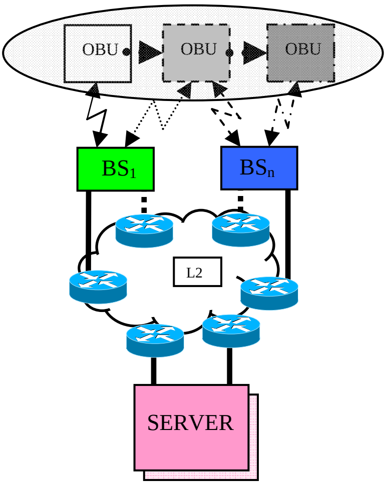

Figure 2. Telematic telecommunications scheme architecture

Structure described on Fig. 3 was later accepted as the typical architecture of ITS telematic solutions. On Board Units (OBU), Sensing System (SS) and set of Wireless Units (WL) are installed in the moving object. OBU represents not only control but also display and operator interface and WL_i represents i-th cellular technology of the wireless complex solution. Terrestrial telecommunications part consists of the set of mobile cellular Base Stations (BS_{ij}) (i-th bases station of the j-th cellular system) integrated by the terrestrial network based on L3/L2 switches/nodes (TN_i) interconnected with Servers (S_i). E2E (End to End) service is provided via IP protocol, L2 switching is Ethernet protocol based.

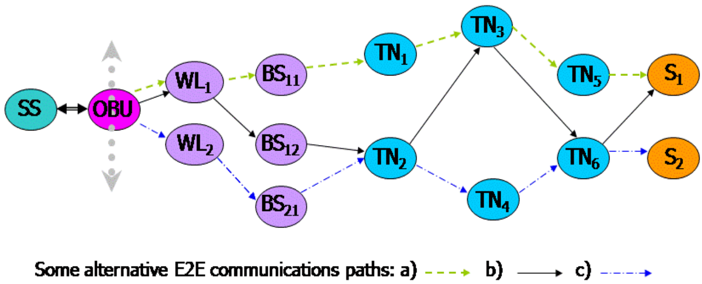

Figure 3. Telematic telecommunications scheme in chain diagram

One access wireless technology can be selected as the core solution and it is substituted by the alternative technology in case it is needed or it is feasible to do so. We will discuss procedures used to select the best possible telecommunications solution being quantified by measured performance indicators as well as by the other parameters like service cost, company policy etc.

3 CALM

The family of standards ISO/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. The process of this alternative solution substitution is understood as the second generation of the handover principle known in its first generation namely from the voice cellular mobile systems.

Each handover process is predestinated by set of parameters range identified for decision processes managed by control unit. The criteria for the “best possible” CALM solution include “external” as well as “internal” performance indicators like Bit Error Rate (BER), packet Round Trip Delay (RTD), level of received radio signal (to be compared with the other base stations being just available) as well as cost of provided service, company policy etc. The control system can take in account not only values of the selected indicators, but it can also evaluate the specific parameters combinations trends. The decision for change can be also caused by the identification of more suitable alternative - e.g. by the appearance of the alternative service with better cost conditions even though existing alternative is still technically sufficient and safe.

The CALM standard resolves described above issue by the vertical system decomposition to the individual subsystems supporting the different telecommunications access solutions. The system management follows the horizontal RM OSI layers principles - see Fig. 4.

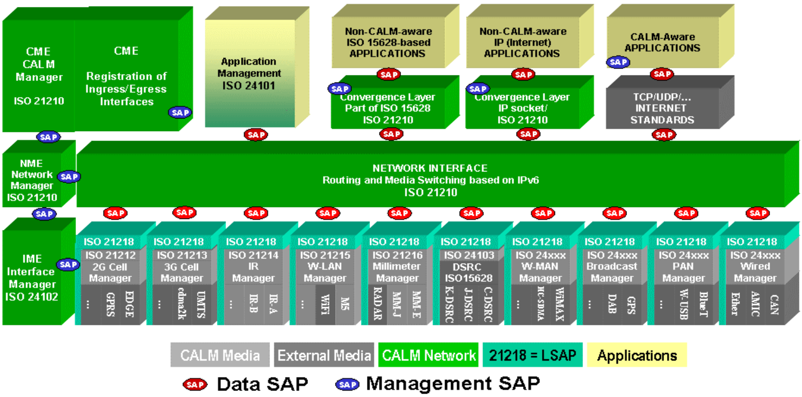

Fig. 4. CALM Layer Architecture (Geneva review)

Details of CALM architecture are described e.g. in [11] and [12]. The CALM system applies exclusively still not widely enough spread IPv6 protocol which allows due to its extensive abilities to continuously remotely trace active applied alternative. The handover is accomplished on the L2 of the TCP (UDP)/IP model.

The handover processes are implemented in the hierarchical telecommunications system with following layer structure (there is not any equivalence with the RM OSI model):

- 1-st layer – Cellular Layer (CL) - represents feed-back control processes of parameters like transmitted power, type of applied modulation or redundancy of applied cannel coding. Main goal of processes on this layer is to keep given set of managed parameters like Bit Error Rate (BER) on L2 or Round Trip Delay (RTD) on L3 within required limits.
- 2-nd layer – the first generation of handover (1HL) - represents the support of process of the seamless switching between the different cells of the same provider's network. Such approach is applied in technologies like GPRS, EDGE, UMTS, Mobile WiMax (IEEE

802.16e), but also in new amendment IEEE 802.11r designed within family of standards IEEE 802.11 (WiFi). This layer use to share information with CL layer (offered usually as one system) so that there is no high risk of contra-productively operated processes on these two layers - of course only in case it is correctly designed and operated.

- 3-rd layer – the second generation of handover (2HL) - is mostly dependent on identification of the service performance indicators. Most of cellular systems is not designed as the open systems with appropriate application interfaces. The interconnection with management of these lower layers is not mostly available. It is for sure that the effective management on the 2HL layer can be much easier reached if 1HL an LC layers share relevant information with managed layer 2HL.

The communications CALM media are accepted in following range:

- Cellular systems including 2G and 2.5G GSM (CSD, HSCSD, GPRS, EDGE) and UMTS,
- DSRC (5.8GHz and 5.9GHz) used primarily for road tolling applications and also for access control,
- Millimeter wave technology (62-63GHz) used in conjunction with radar signal at similar frequencies,
- Satellite telecommunications exclusively applied for emergency and “special applications”,
- IR (Infra Read) telecommunications solutions,
- WiFi (IEEE 802.11 based) different alternatives - a, b, g, n,
- WiMax (IEEE 802.16d) and Mobile WiMax (ext. IEEE 802.16e)
- M5 based on standard IEEE 802.11p,
- IEEE 802.15.x based solutions: Bluetooth – 15.1, UWB (Ultra Wide Band) - 15.3, ZigBee - 15.4,
- W-USB (Wireless USB)
- Other media to come.

Some of listed technologies (DSRC, Bluetooth, ZigBee, UWB, IR, RFID systems) operate exclusively on a short distance. This type of telecommunications technology is applied e.g. for widely spread DSRC based tall collection systems or for the enforcement support of the GNSS based tall collection system. 5.9GHz DSRC version (designed for USA) is now ready to support a Car2Car communication. This telecommunications tools are as well quite frequently applied in the "nomadic" regime for the specific mostly static applications like the data exchange between Car and Infrastructure in hot spots, parking areas etc.

3.1 Multi-path L3/L2 PBM based switching

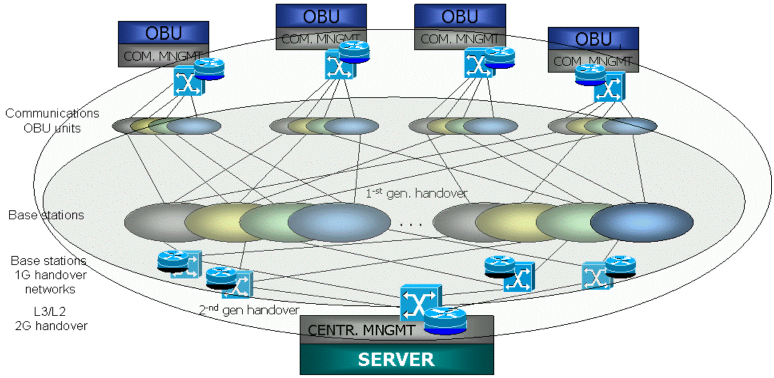

Figure 5. L3/L2 Switching based 2nd generation of handover.

The decision processes representing basis for adaptability of telecommunications wireless services have not been deeply enough resolved issue within CALM documents. Data services solutions are mostly based on the Policy-Based Management (PBM). L3/L2 switching based alternative is presented on scheme described on Figure 5.

The PBM concept has been traditionally applied in the IP based networking and we can only state its remarkable success. This approach can be combined with the Model Driven Architecture approach employing models, and precisely the Object management Group (OMG) Model Driven Architecture (MDA). Authors of such approach [14] integrated language- and middleware-neutral features into adaptive services. A POETRY service creation framework described in [14] applies the PBM method to describe and control internal logic of the adaptive services and simultaneously a method based on the MDA model is used to describe the adaptive service informatics model.

3.2 Multi-path adaptive classification process

An alternative approach applies a complex approach based on statistics with limits given by the CPU capacity. Nevertheless, main driver of such approach is based on idea to provide a general adaptive solution with ability to process continuously in time changing performance indicators. Such approach leads to the decision scheme which is not only based on the performance indicators status but also on the evaluation of the selection of the performance indicators trends.

As already mentioned such complex mathematical solution can easily use remarkable capacity of the applied CPU. We can so expect that presented complex mathematical solution will be effectively combined with the PBM approach namely thanks to the IP nature of the data telecommunications.

Following paragraphs describe one of the potential approaches to the decision processes. Proposed methodology is based on following principles - see [18] - [20]:

- Measured parameters are filtered e.g. by a 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 economical parameters, corporate policy etc. and result is marked as vector **x.**
- Based on the time lines of vector **x** it is feasible to classify the best possible technology selection. The classification algorithm is trained using the time lines of training vectors **x** extended by assignment to the relevant class, i.e. selected path.
- The classification process success depends to the training data size and data quality.

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 [19].

Let us define the classification problem as an allocation of the feature vector $\mathbf{x} \in R^D$ 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 telecommunications technology based on knowledge of **x** vector – see e.g. [19].

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

$$\hat{f}(\mathbf{x} \mid \omega) = \frac{1}{N_\omega \cdot h_\omega^D} \cdot \sum_{i=1}^{N_\omega} K\left(\frac{\mathbf{x} - \mathbf{x}_i^\omega}{h_\omega}\right), \tag{7}$$

where $K(\cdot\cdot)$ is a kernel function, $\boldsymbol{h}_\omega$ is a smoothing parameter for ω-th class, N_ω is sample count in class ω and $\mathbf{x}_1^\omega, \ldots, \mathbf{x}_{N_\omega}^\omega$ is the independent training data.

We use the Laplace kernel defined by the following Laplace density function:

$$f_L(x;\mu,\sigma) = \frac{1}{2\cdot\sigma} \cdot \exp\left(-\frac{|x-\mu|}{\sigma}\right), \tag{8}$$

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

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

$$\hat{f}(\mathbf{x}|\omega) = \frac{1}{N_\omega} \sum_{i=1}^{N_\omega} \prod_{j=1}^{D} \frac{1}{2\cdot h_{\omega,j}} \exp\left(-\frac{|x_j - x_{i,j}^\omega|}{h_{\omega,j}}\right). \tag{9}$$

Smoothing vectors are optimized by a pseudo-likelihood cross-validation method using the Expectation-Maximizations (EM) algorithm - see [19].

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 $\mathbf{x} \in \mathrm{R}^D$ takes value to one of C mutually exclusive classes $\Omega = \{\omega_1, \ldots, \omega_C\}$. The probabilistic measure $Q_{d,i,j}(d, \omega_i, \omega_j)$ of two classes separability for the feature d (d-th component of feature vector) is defined as

$$Q_{d,i,j}(d, \omega_i, \omega_j) = \frac{\eta \cdot (\sigma_i + \sigma_j)}{|\mu_i - \mu_j|}, \tag{10}$$

where ω_i and ω_j are classes and symbol $\eta = 3.0$ denotes the real constant which specifies 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 is 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.

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

$$Q(d) = \sum_{i=1}^{C} \sum_{\substack{j=1 \\ i \neq j}}^{C} Q_{d,i,j}(d,i,j). \qquad (11)$$

All features in 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 just linear separability. On the other hand, the individual feature selection method based on the between-to within-class variance ratio is very fast.

Presented method is applicable for the complex decision processes developed in order to select the best possible alternative access out of any set of available active paths. Fact that the decision is based on evaluation of both measured as well as determined parameters represents another remarkable advantage of this presented method. Introduced method enables to prolong the training process into the application period as well as this method is open for any future information resources extension (namely originated in 1HL and CL layers). Such approach leads to step by step decision process quality improvement.

The presented method does not necessarily require any information from autonomously managed layers 1HL and CL. System instability if the lower layer management actions are not synchronized with the top layer management can easily appear. To minimize contra productive actions on the different layers it is necessary to follow the CALM management interconnecting approach - see Fig. 4. It is not necessary to centralize all decision in one decisions center, however, the successful solution can be archived if the effectively designed synchronization scheme is applied.

4 PROPERTIES OF GSM DATA SERVICES

Many users assume that the GSM mobile network can provide widely spread fast and reliable data service with reasonable signal coverage and high level of service availability. However, practical ITS implementation identified quite a significant problem with performance of the GSM data services if applied within telematic applications.

Main objective of the presented results is to identify the performance indicators range these services can provide for the ITS applications. It is feasible to recognize the additional “internal” performance indicators which can be applied for decision processes as instrumental information. *C/I* (*C* is the total signal power and *I* represents Interference (noise) power) was identified as such relevant “internal” performance indicator and its impact on the overall data service performance indicators will be presented.

Impact of the total GSM network load and provider’s services preference management is measurable exclusively by the service performance indicators (L3). Every “CALM decision” must in case *C/I* value is above the critical level take in account also the values of service performance indicators measured on the IP layer.

The GSM channel bandwidth is fixed to 200 kHz so that the ratio *C/I* represents the critical parameter which principally influence the GSM data services performance expressed by the performance indicators (see Shannon - Hartley theorem):

- Data Channel Capacity *CC*,
- Packets Loss Ratio (PLR),
- Packet Round Trip Delay (RTD).

All above mentioned parameters can be identified by the appropriate IP tools of the IP layer.

4.1 Methodology of measurement

Each of available 2.5 GSM generation data services i.e. CSD, HSCSD, GPRS and EDGE was studied individually. We have got unique opportunity to measure the performance parameters of the GSM services in one of the GSM provider’s laboratory equipped by locally manageable fully calibrated base station with adjustable transmitter output power - see [24]. Additionally the noise signal with adjustable power *I* was generated by the external calibrated noise generator. The power of the base station was set for each measurement period on the defined level *C* and power of noise *I* generated by the additional noise generator was step by step changed within the reasonable limits.

The service quality measurement was processed based on application of the L3 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 the minimal service response time.

4.2 Results

4.2.1 CSD Technology

Tab. 1 and Fig. 6 show that the CDS technology causes packet delivery delay in the sub-second range. Studied service has relatively low sensitivity on the parameter *C/I*, i.e. signal to notice ratio. However, it must be stressed that the CSD service represents a circuit switched alternative with all known disadvantages of this approach comparing with the packed based GPRS/EDGE.

Table 1. Basic data for CSD technology

C/I	**Packets**			**RTD [ms]**		
	Sent	**Received**	**Lost**	**Min**	**Max**	**Avg**
4,074	100	95	5	880	2844	1084
3,890	100	90	10	886	3558	1145
3,715	100	91	9	883	1689	956
3,548	100	88	12	728	1253	927
3,388	100	94	6	885	2195	970
3,236	100	95	5	877	4139	1048
3,090	100	90	10	723	4421	1004
2,951	100	85	15	835	3300	1005
2,818	100	91	9	877	2996	1066
2,692	100	90	10	888	3765	1072
2,570	100	89	11	841	4091	1085
2,455	100	89	11	884	2300	1044
2,344	100	93	7	888	3917	1116
2,239	100	89	11	756	3401	1126
2,138	100	57	43	887	3891	1250
2,089	100	84	16	889	3728	1177
2,042	100	41	59	897	3217	1236
1,995	100	59	41	844	3659	1208
1,950	100	16	84	936	4162	1886
1,862	100	5	95	920	3362	2169
1,778	100	0	100			

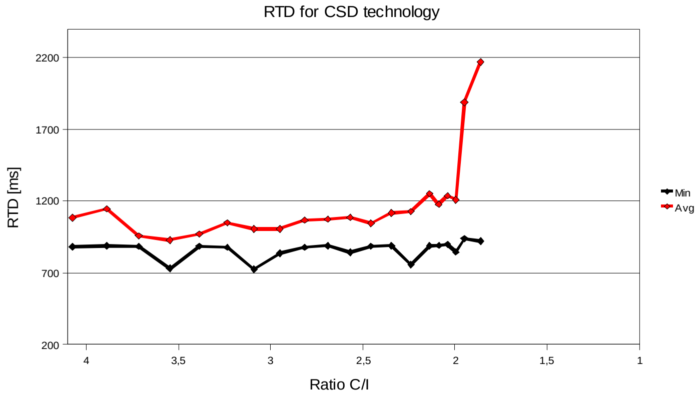

Figure 6. RTD for CSD technology

4.2.2 HSCSD Technology

The results obtained for the CDS technology measurement displayed on Tab. 1 and Fig. 6 are valid for the HSCDS technology, as well. The only difference is in channel capacity due to fact that the increase in the capacity is exclusively obtained by the increase of the applied time slots number.

4.2.3 GPRS

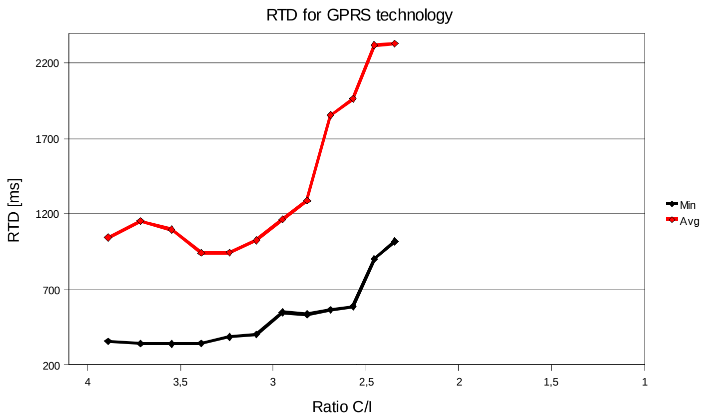

Figure 7. RTD for GPRS technology

GPRS technology provides similar dynamical parameters as were identified for the CSD (see Fig. 7), however, only in case *C/I* > 2.8. Principal RTD as well as packet loss increase can be identified for *C/I* < 2.8.

The advantage of the GPRS service can be understood in its packed based concept. Nevertheless, the GPRS services are applicable only for "less demanding" applications where long delays and high potential of packet losses are not critical or in case the GPRS service can be effectively combined with alternative technologies on e.g. the CALM principles.

4.2.4 EDGE

Identified EDGE average delay represents the most reasonable result of all GSM alternatives and critical level of the packet loss is reached at unbeatable value of ratio *C/I* = 1.2. Even though this technology offers the best of all GSM data services parameters acceptable for much wider range of the ITS applications there still remains fact that quality of service depends on the status of the network which is not quantified by any explicit parameter.

Service providers offer data services exclusively in the best effort regime – i.e. no guaranteed GSM data service is offered. It must be stressed that *C/I* parameter identifies the only potential to reach required quality of service. If *C/I* measurement identifies potential of acceptable quality such result must be verified by identification of the actual data service performance indicators to eliminate any problems caused by the potential interaction with any other customers served on the same network.

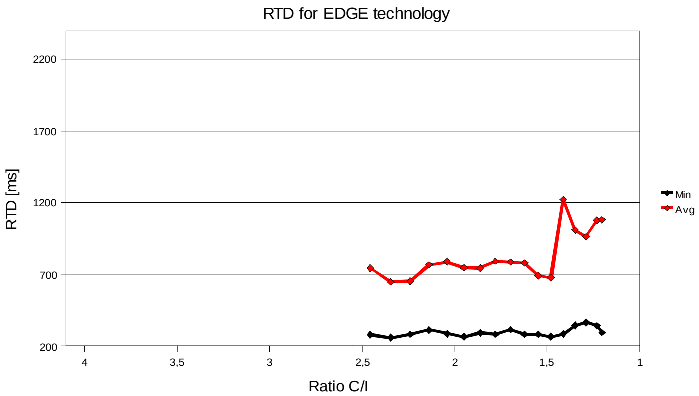

Figure 8. RTD for EDGE technology

4.2.5 GSM data services properties within ITS applications

The GSM service was originally designed to provide public mobile voice and low speed (9,6kb/s) circuit switched data service. In the 2.5G GSM generation packet data services with limited capacity dedicated to each terminal were adopted. The GSM service providers are concentrated on their core business, i.e. high quality mobile voice services, and, the data services are provided as “complementary” products with no guaranteed quality of service. If the network capacity is required for the voice service provisioning the data service capacity can be considerably reduced or data service can be practically disabled.

This disadvantage could be resolved by partial network capacity dedication to “special” services with management concentrated on provisioning of guaranteed service quality. The European Commission recently introduced new rules how could be the limited part the service provider’s network capacity fairly shared with the “virtual” operators. Such activities, however, do not have good chance to be accepted soon due to strong “self-defense” effort of the powerful mobile operators.

Originally expected data services of global coverage based on the 3^{-rd} generation mobile data service (UMTS) have been late and they do not have potential for reaching rural areas. Beyond 3^{-rd} generation solutions (LTE) are very promising future solutions, however, such services cannot be expected sooner than in the next decade (2011-3).

We can identify very strong potential to improve the data services quality even though the data services remain to be dominantly delivered by the GSM providers. Such approach is based on the combination of relatively inexpensive widely available public GSM service with the alternative well manageable services. This principle can be effectively applied namely if the GSM provider’s infrastructure can be shared by the other potential technologies. The alternative services should be applied to fill the services coverage gaps when/where the core GSM wireless network cannot provide service on the required quality level. The solutions based on the IEEE 802.16d/e standards known as the (Mobile) WiMax represents one of the most promising alternatives. This technology (in version “d”) was tested e.g. in already mentioned project CAMNA.

Together with the GSM and the (Mobile) WiMAX services the DSRC (Dedicated Short-Range Communications) designed for transport telematics, minimally one representative of the PAN (Personal Access Network) solutions and the automotive CAN bus (Controller Area Network) should be adopted by the universal OBU to cover the substantial range of the telecommunications services required by the transport telematics applications.

5 WiMAX SOLUTION

We had unique opportunity to process the detailed WiMax technology performance measurement within the “real life” applications - see e.g. [7] - [9]. Basic results from the WiMax measurement are available in Table 4. – provided by the WiMax management system.

Table 2. Parameters of the WiMax access

Visibility	ARTD [ms]	SNR [db]
LOS	45.6	33
LOS	47.1	32
NLOS	44.6	-26
NLOS	44.8	-27

where ARTD means “Average Round Trip Delay”, SNR “Signal to Noise Ratio”, LOS “Line Of Sigh” and NLOS “Non LOS”. Spectra of Round Trip Delay (RTD) in ms are displayed for LOS regime on Fig. 8 and for NLOS alternative on Fig. 9. Obtained average delay for both cases is shorter than 50ms. WiMax systems provide wireless access service where parameter ARTD can reach less than 10% of ARTD provided by the GSM data services. Additionally the WiMax system can offer different selectable levels of guaranteed service quality (QoS).

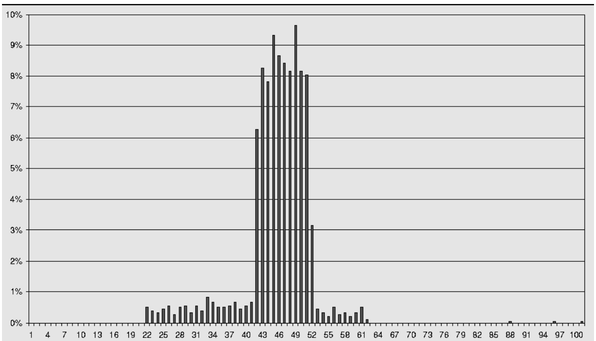

Figure 9. RTD spectra of LOS

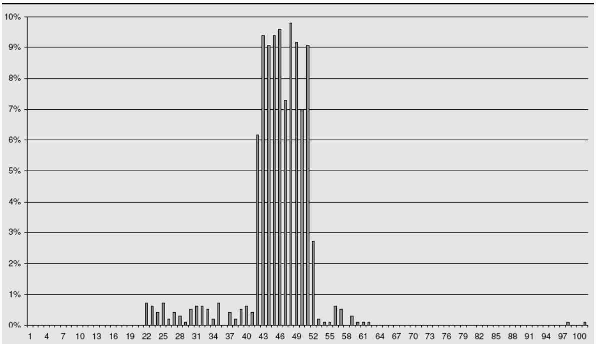

Figure 10. RTD spectra of NLOS

However, due to complex situation in the mobile services industry we cannot even only estimate time period the WiMax or any other relevant technology can be accepted by the GSM providers to be applied as appropriate alternative solution (if ever accepted).

In order to precisely identify available set of the representative "internal" performance indicators and their impact on the "external" performance indicators the detailed study of selected WiMax module/modules must be processed. All the other potentially applied technologies must go through the same complex procedure. Tools for the representative monitoring and the efficient remote control of the internal processes must be identified for each applied module to be able to secure appropriate stability of the whole system based on the efficient different layers processes synchronization

6 IMPLEMENTATION OF PROCESSES INTO MARKET AVAILABLE SYSTEMS

General architecture accepted by the CALM standards (see Fig. 4) represents very transparent matrix approach to the design of the telecommunications system corresponding with the "carrier grade" systems approach. However, investment into the R&D and the chip sets/modules production is driven namely by requirements of the terminals designed for the mass market. This area is well known with its "liberal" approach to the transparency of the system architecture. Before the On Board Unit (OBU) is installed in (minimally) every new car with result of the mass production of such units the OBU designers will most probably have to accept trends caused by the public multifunctional terminals approach.

We have designed in close cooperation with experts of the company Freescale (originally part of Motorola) an alternative to the CALM architecture with the aim to provide the "best possible" multipath telecommunications solution. Obtained result is presented on Fig. 11 and it is clear that it does not meet requirement of the CALM transparent matrix architecture.

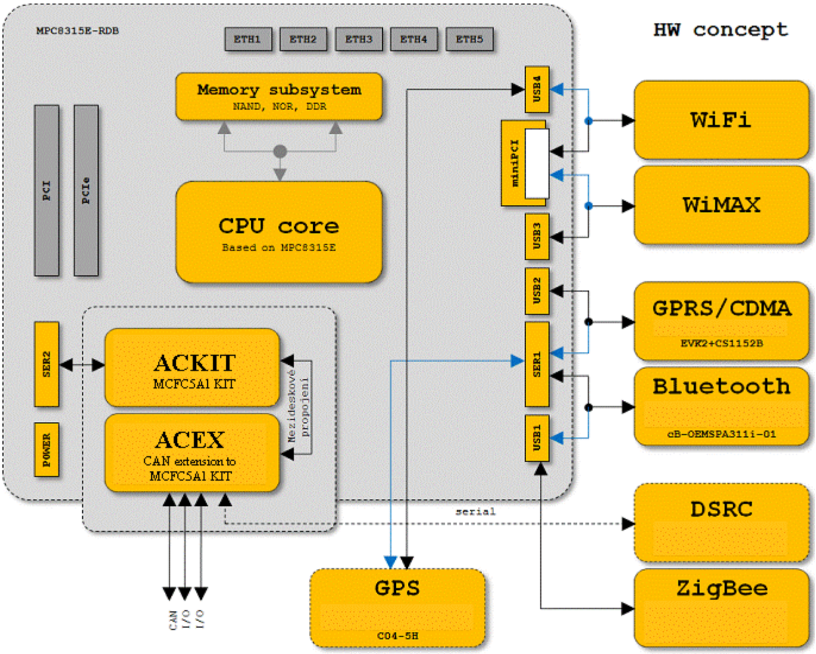

Figure 11. Telecommunications solution

based on Frescale Chip sets/modules.

As an advantage of such solution is the possibility to reach the realistic realization time horizon as well as the acceptable pricing of such solution. Such approach to the unit design can lead to the "One OBU on board for all telematic services". Such requirement represents e.g. the internationally interoperable hybrid tolling functionality combined with the support of the wide range of different telematic services including e.g. the dynamic navigation.

Another OBU designed to support the multi-path telecommunications solution will be available as the result of the project SRATVU[2]. This unit is

[2] "System Requirements and Architecture of the universal Telematic Vehicle Unit" is grant 2A-1TP1/138 of Ministry of Industry and Trade of the Czech Republic.

being developed by our project partners. Laboratory e-Ident founded within project E-IDENT[3] has got chance to examine all OBU modules and developed transport telematics services. These activities also opened unique opportunity to tests the first pilot solution of the multi-path telecommunications sub-system hopefully before the end of the year 2009. Prior to the first version of the decision processes package is implemented the appropriate above described identification of selected telecommunications modules must be finalized.

7 CONCLUSIONS

The seamless switched combination of the wireless access solutions of either the same or the alternative technologies and providers was identified as the answer on the urgent ITS solutions demand.

The multi-path access solutions switching is a subject of intensive R&D and it is also area widely discussed within the ISO/CEN CALM standards initiative. These standards are mainly focused on the system architecture and switching tools. Decision schemes have not got the high priority and the Policy-based Management (PBM) traditionally applied in IP based data networks is mostly accepted as sufficient tool. Remarkable number of IP networks installations can confirm this statement. However, such approach can deteriorate possible application of managerial data available from the lower layers.

The proposed alternative of adaptive decision processes is based on the self trained classification. Proposed classification algorithm is trained by the training time line of data vectors extended by the assignment of the each data vector to the correct class, i.e. path. The success of classification process depends on quality of the training data. However, decision processes can be improved continuously if the self training processes are further processed in the application period.

The above described method theoretically allows implementation with no information flow between the top control layer 2HL and the lower 1HL and CL layers. These two “lower” layers are usually autonomously managed. Such approach, however, can cause the whole system instability. In order to minimize contra-productive actions on the different control

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[3] e-IDENT – Electronic identification systems within transport process –is grant 2A-2TP1/108 of Ministry of Industry and Trade of the Czech Republic.

layers it is necessary to provide efficient synchronization of different layers decisions centers.

2.5G GSM data services are optional extension of the massively accepted mobile wireless voice services. GSM services providers, however, emphasize the public mobile voice services quality management, and, data services are mostly provided only in “best effort” regime.

In the “Revision of the European e-communications regulatory framework” have been proposed provisions for the virtual services provider’s existence. Virtual providers could e.g. offer wireless telecommunications services with guaranteed quality. This initiative, however, might not be accepted mainly due to strong “self-defense” lobbing of the powerful mobile operators in the near future.

Authors of the 3rd generation (UMTS) data services have resolved most of discussed problems. This service coverage does not have potential for remarkable growth so that this service provisioning will be concentrated only on the highly populated areas. “Beyond 3rd generation” solutions (LTE) are very promising future data solutions. However, availability of these services cannot be expected sooner than within a few years.

A potential for meeting ITS solutions requirements on specific parameters of the telecommunications solutions was identified in combination of the GSM data services with alternative telecommunications wireless services, namely if these solutions can share the widely spread GSM services provider’s infrastructure. Alternative services are dedicated to fill services gaps which cannot be resolved either permanently or only under specific conditions by the core wireless service. Technology based on standards IEEE 802.16d/(e) known as (Mobile) WiMax represents one of the most promising alternatives. Such access solution was successfully tested e.g. within project CAMNA and it was applied in telematics solution, where capacity and reliability of GSM service was recognized as insufficient.

Additionally, automotive CAN bus implemented in wide range of modifications, DSRC (Dedicated Short-Range Communications) designed for transport telematics and minimally one representative of PAN solutions should be included in the OBU telecommunications services portfolio. The presented system architecture is ready for these described above technologies integration.

The multi-path wireless access solution treated by family of CALM standards has accepted transparent matrix architecture, i.e. the same approach which has been adopted by the “carrier grade” telecommunications systems designers. Current trend in chip sets and modules R&D and production does not mostly meet the “carrier grade” solutions conventions, as they mostly follow the mass market terminals needs. Mass market terminal area has in comparison with the “carrier grade” solutions more “liberal” approach to the system architecture. Until OBU is massively installed in all vehicles, which will significantly influence the OBU production volumes, conditions of OBU designers will most likely remain unchanged. Therefore it will be necessary to invent the compromise approach of the OBU designers who will have to take in account rules formed as a result of the mass market terminals dominance.

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- Strategické plánování, vývoj a management podnikatelských projektů,
- Vývoj partnerských vztahů s dodavateli technologií a strategickými zákazníky,
- Management provozu datových sítí a služeb a rozvoj datových služeb.

1993 - 1996 EuroTel Praha / NEXTEL, o.z.
Produktový Manager

- Produktový manager přístupových a záložních páteřních služeb VSAT a terestrických datových služeb X.25 a FR,

1989 - 1993 ČSAV, Geofyzikální ústav
vědecký pracovník, vědecký tajemník (1990-93),
člen ekonomické rady Prezídia ČSAV (1990 –93)

- Identifikace vlastností a modelování magnetických struktur syntetických a jednoduchých přírodních materiálů s využitím Preizachova modelu a jeho On-Line identifikace,
- Výzkum experimentálních geofyzikálních laboratorních metod, řízení experimentu, zpracování a archivace dat,
- Výzkum observatorních geofyzikálních metod, sběru a přenosu dat.

1972 - 1976 VÚAP Praha
vývojový pracovník

- Vývoj automatických systémů řízení technologických procesů s využitím dostupných minipočítačů,
- Datové komunikace v rámci řízení technologických procesů – specificky podíl v projektu IVU- 800.

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3. T. Zelinka, V. Kropáček, J. Tauer, *Rock Magnetism Meassuring Technique and Apparatus,*. The Encyclopedia of Solid Earth Geophysics. Ed. D. James, Van Nonstrad Reinold Comp., New York 1989, 950 – 961.
4. P. Hejda, T. Zelinka, *Modelling of hysteresis processes in magnetic rock samples using the Preisach diagram,* (1990) Physics of the Earth & Planetary Interiors 63 (1-2), pp. 32-40. Cited 19 times (SCOPUS).
5. J. P. Cogne, N. Bonhommet, V. Kropacek, T. Zelinka, E.: Petrovski, *Paleomagnetism and magnetic fabric of the deformed redbeds of the Cap de la Chevre Formation, Brittany, France* (1991) Physics of the Earth & Planetary Interiors 67 (3-4), pp. 374-388. Cited 5 times (SCOPUS).
6. M. Svítek, T. Zelinka, *Communications Solutions for ITS Telematic Subsystems,* WSEAS Transactions on Business and Economics Issue 4 (2006), Vol. 3, pp 361 – 367, ISSN 1109-9526.
7. T. Zelinka, M. Svítek, *Communication solution for Vehicles Navigation on the Airport territory,* Proceedings of the 2007 IEEE Intelligent Vehicle Symposium, Istanbul, Turkey, pp 528–534, IEEE Catalogue No. 07TH8947, ISBN 1-4244-1068-1.
8. T. Zelinka, M. Svítek, *Communication Scheme of Airport Over-ground Traffic Navigation System,* Proceedings of the International Symposium on Communications and Information Technologies - ISCIT 2007. IEEE Sydney, 2007, pp 329 - 334. IEEE Catalogue No. 07EX1682(C), ISBN 1-4244-977-2, Library of Congress 2007920360.
9. M. Svítek, T. Zelinka, *Communications multi-path access decision scheme*, Neural Network World, Praha, No. 6.,2008, pp 3 - 14, 2008, ISSN 1210 0552.
10. T. Zelinka, M. Svítek, *Identification of Communication Solution designated for Transport Telematic Applications,* WSEAS Transactions on Com., Issue 2, Volume 7, 2008, pp 114 – 122, ISSN: 1109-2742.
11. M. Svítek, T. Zelinka, *ITS Multi-path Communications Access Decision Scheme*, Journal of Systemics, Cybernetics and Informatics, IIIC, Volume 6, No.1, Orlando, 2008, ISSN: 1690-4524.
12. T. Zelinka, M. Svítek, *Adaptive com. solutions in complex transport telematics systems,* Computers and Simulation in Modern Science II, WSEAS Press, Athens, 2009, pp 213 -241, ISBN 978-960-474-032-1.