Identification of Communication Solution designated for Transport Telematic Applications

TOMAS ZELINKA
MIROSLAV SVITEK
Faculty of Transportation Sciences
Czech Technical University in Prague,
Konviktská 20, 110 00 Prague 1,
CZECH REPUBLIC
E-mail: zelinka@fd.cvut.cz, svitek@fd.cvut.cz, http://www.fd.cvut.cz

Abstract: - Communications solution represents one of the key parts of the Intelligent Transport system (ITS). Goal of our research is to improve over-ground traffic efficiency and security, specifically on the airport territory, where pilot installation was set-up and tested with aim to confirm its ability to improve conditions for efficient management of the over-ground traffic of all moving object in area including moving aircrafts and all types of service vehicles. ITS system requirements on the communications environment are usually quantified indirectly by telematic sub-system performance indicators. Correct selection and configuration of the appropriate communication solution are achievable, if "transformation matrix" between vectors of communications and telematic performance indicators is correctly identified. Principles of developed method based on such transformation matrix identification are introduced. Application of the proposed methodology is demonstrated on the CaMNA communications system identification and its parameters settings. Airport territory has got quite complex arrangement and there are very different requirements on telematic system performance in different parts of the airport area. This fact leads to application core wireless access service securely combined with set of the alternative technologies applied in areas, where the core service is not available for technical or economical reason. Management of such system is based on implementation of the CALM family of standards or its mutations with implemented effective and safe decision processes. Correctly designed decision processes supporting selection of the "best possible" alternative represent one of key issues of the whole solution. Results of the communication solution parameters tests processed within limited pilot installation and relevant recommendations are presented as the last part of this paper.

Key-Words: - Intelligent Transport Systems, Telecommunications Performance Indicators, Telematic Performance Indicators, Global Navigation Satellite System, handover, Quality of Service

1. Introduction

New method of the communication system identification and configuration based on principles described in [1] and [2] was developed within projects e-Ident[1], DOTEK[2] and SRATVU[3] elaborating results of project CAMNA[4]. The main goal of those projects is to improve efficiency and security of the over-ground vehicles traffic, specifically movement of all service vehicles on the airport territory as well as all individual aircrafts. This telematic application based on GNSS (Global Navigation Satellite System) is developed to be integrated with already operated management systems A-SMGCS (Advanced Surface Movement Guidance and Control System) based on the non-GNSS based localization systems. System is designed in client – server structure – see Fig. 1. Powerful client is inevitable to be installed in every vehicle used at airport area. Client, i.e. OBU (On Board Unit) is designed as a modular system equipped with powerful PC based unit. Right now are available modules like GNSS unit, wireless communications units, display and audio unit. Both SW and HW modular architecture gives to designed system remarkable potential to extend/change functionality of the system by means of a newly integrated modules.

Information about vehicle position is sent to the central server on periodical basis together with requirements generated by vehicle driver. Server collects and processes data received from all service vehicles. Obtained information is combined with data gained from A-SMGCS, processed and result is delivered to the airport management display unit, as well as to each

[1] e-Ident – Electronic identification systems within transport process – grant of MPO CR 2A-2TP1/108.

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

[3] SRATVU – "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

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

vehicle equipped with active OBU. Each OBU receives also managerial data generated by either airport control system or by dispatchers. OBU screen shares positional information with received administrative data.

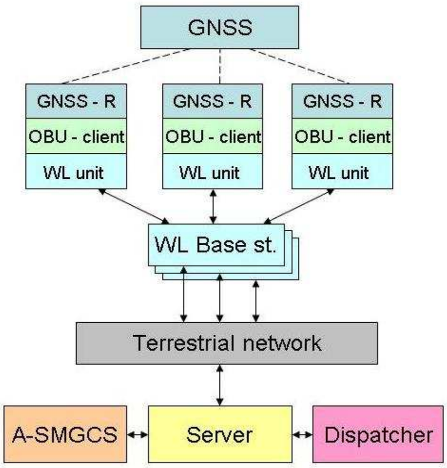

Figure 1. CAMNA telematic service structure

Described client-server application can resemble the widely spread publicly available car navigation systems. However, this application displays all identified objects in the area on both dispatcher as well as users units and extensive set of bidirectional interactivity tools is available, as well. There are above average requirements on telematic system performance indicators. This fact is caused by specific conditions this application is operated on the airport area.

2. Communications solution

2.1 Telematic sub-system requirements

Airport is strictly, but precisely and transparently regulated area and telematic sub-system performance indicators (see e.g. [2] – [5]) were identified in Table 1.

Perform. Indicator	limit value	probability level	time interval
Accuracy	7.5m	99%	-
Availability	30s	99%	after init.
Reliability	36s	99%	3,600s
Continuity	5s	99%	180s
Integrity	5s	99%	-

Tab.1 Required Telematics Performance Indicators

Full mobility of the communication solution represents one of the crucial system properties specifically in context of particular demand on availability, quality and security of applied communication solution.

Required data transmission capacity represents another critical system parameter. In TCP/IP communication structure one positional data *pd* represents approx. 70 Bytes. If position each of *n* object is identified by GNSS method and *m* additional object are localized by A-SMGCS both with frequency *f* than needed transfer capacity for localization data flow between server and clients is

$$tci = pd.n.f.(n+m).8 \text{ [b/s]}. \quad (1)$$

In case e.g. $n = 100$, $m = 100$ and $f = 1s^{-1}$ than $tci = 11.2Mb/s$. Required transferred capacity for localization data in opposite direction, i.e. from client to server is

$$tcc = pd.n.f.8 \text{ [b/s]}. \quad (2)$$

If broadcast regime instead of the individual communication between server and clients is applied, the data transfer

$$tcb = pd.f.(n+m).8 \text{ [b/s]}. \quad (3)$$

Any other individual supervisory server to clients data flows are additional that value. In broadcast regime data flow from server to clients is

$$tcb = tci / n \text{ [b/s]}. \quad (4)$$

Additional individual managerial data flows between server and clients are not, however, included in this ratio. There is available alternative principal reduction of the transmitted data volume reached if positional data are selectively transmitted to each moving object with individual period. Distance between objects and their mutual speed represent effective criteria for such data flow control.

Generally accepted IP protocol offers transparent interoperability paid by need of wide range of techniques and tools, which must be carefully installed and managed to obtain requested service quality, reliability and security. Telematic real-time applications frequently strictly require precise specification, control and continuous monitoring of the services parameters.

Physical layer (L1) has been essentially improving its quality parameters. Due to this fact link layer (L2) BER (Bit Error Rate) is today reaching level of 10^{-9} in case of carrier grade wireless systems and up to 10^{-12} for fiber networks. L1 has got so minor influence on the communication system BER. On the other hand due to packet/frame information structure L3 and L2 nodes performance is critical for the whole communications systems system parameters. Following communications performance indicators quantify service quality:

- *Availability,*
  - *Service Activation Time* (SAT) - defined as time needed for activation/modification of the network archived on certain probability level,
  - *Mean Time to Restore* (MTTR) - defined as time service is restored from unexpected inoperable stage on certain probability level,
  - *Mean Time Between Failure* (MTBF) - defined as time between two unexpected inoperable stages on certain probability level and

  - *VC availability* - percentage of correctly provided service in appointed time interval on certain probability level.
- *Delay* - an accumulative parameter defined as time frames are delivered within a defined time period on a certain probability level. This parameter is effected by *(i) interfaces rates (ii) links capacity, (iii) frame size, and (iv) load/congestion* of all in line active nodes (switches).
- *Packet/Frames Loss* - percentage of undelivered packets/frames within defined time period on certain probability level.
- *Security* - Risk Analysis (RA) and classification must be done based on detailed knowledge of the system environment and potential risks. Risk of information integrity can be caused by attack on any part of the information transfer chain. Relevant solutions can be seen namely in additional security tools – like on L2 authentication, coding and on application layer - authentication, coding and tunneling.

2.2 Communications design methodology

Performance indicators described for communications applications must be transformed into telematic performance indicators structure, and vice versa. Such transformation allows system synthesis. Final additive impact of the vector of communications performance indicators $\overrightarrow{tci}$ on the vector of telematic performance indicators $\Delta\,\overrightarrow{tmi}$ can be expressed by following equation, however, only under condition that probability levels of all indicators are unified on the same level and all indicators are expressed exclusively by time or on time convertable value:

$$\Delta\overrightarrow{tmi} = TM \cdot \overrightarrow{tci}, \qquad (5)$$

where *TM* is transformation matrix. Identification of the *TM* represents transparent process and it is handled in four iterative steps. Identification process starts with matrix in the most general structure - TM_0. The transformation matrix TM_0 takes in account all potential relations between telecommunications and the telematic indicators. Probability of their appearance in context of the other processes is not evaluated in-depth in this step. Matrix construction is logically dependent on the detailed communication solution configuration.

Vector $\overrightarrow{tmi}$ consists of:

- *Accuracy* p_i ,
- *Availability* $t_{ds,i}$,
- *Reliability* $t_{tna,i}$,
- *Continuity* t_i ,
- *Integrity* $t_{tsna,i}$.

Vector $\overrightarrow{tci}$ is for described application :

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

General impact of listed set of communications performance indicators on above defined set of telematic performance indicators is described for parameters:

Accuracy as distance vehicle maximally moves within whole communication cycle

$$\Delta p_i = v_i * \begin{pmatrix} d_{u,i} + rc_{hs,m,i} + rc_{hd,m,i} + rc_{rp,m,i} + \\ + rc_{r,f,i} + rc_{r,m,i} + d_{d,i} + t_{na,m,i} + t_{na,f,i} \end{pmatrix}, \qquad (6)$$

Availability as time required to accept wireless unit into network plus time to deliver information about successful acceptance

$$\Delta t_{ds,i} = t_{oi,i} + d_{d,i} + rc_{hs,m,i} + rc_{hd,m,i} + rc_{rp,m,i} + \\ + rc_{r,f,i} + rc_{r,m,i} + d_{u,i} + t_{na,f,i} + t_{na,m,i}, \qquad (7)$$

Reliability as time service is not available within defined period

$$\Delta t_{tna,i} = t_{na,f,i} + t_{na,m,i} + ns_{hsm,i} * rc_{hs,m,i} + \\ + ns_{hdm,i} * rc_{hd,m,i} + ns_{rpm,i} * rc_{rp,m,i} + \\ + ns_{sf,i} * rc_{r,f,i} + ns_{rm,i} * rc_{r,m,i}, \qquad (8)$$

Continuity as time period communications service is not available

$$\Delta t_i = rc_{hs,m,i} + rc_{hd,m,i} + rc_{rp,m,i} + \\ + rc_{r,f,i} + rc_{r,m,i} + t_{na,m,i}, \qquad (9)$$

Integrity as time to deliver information about system failure

$$\Delta t_{tsna,i} = rc_{hs,m,i} + rc_{hd,m,i} + rc_{rp,m,i} + \\ + rc_{r,f,i} + rc_{r,m,i} + d_{d,i} + t_{na,f,i} + t_{na,m,i}. \qquad (10)$$

Transormation matrix structuture for this set of parameters deffined in Eq. (5) is

$$TM=\begin{bmatrix} k_{p,u,i}\cdot v_i, & k_{p,d,i}\cdot v_i, & k_{p,hs,m,i}\cdot v_i, & k_{p,hd,m,i}\cdot v_i, & k_{p,rp,m,i}\cdot v_i, & k_{p,r,f,i}\cdot v_i, & k_{p,r,m,i}\cdot v_i, & k_{p,na,f,i}\cdot v_i & k_{p,na,m,i}\cdot v_i & 0 \\ k_{d,u,i}, & k_{d,d,i}, & k_{d,hs,m,i}, & k_{d,hd,m,i}, & k_{d,rp,m,i}, & k_{d,r,f,i}, & k_{d,r,m,i}, & k_{d,na,f,i}, & k_{d,na,m,i}, & k_{d,oi,i} \\ k_{s,u,i}, & k_{s,d,i}, & k_{s,hs,m,i}\cdot ns_{hs,m,i}, & k_{s,hd,m,i}\cdot ns_{hd,m,i}, & k_{s,rp,m,i}\cdot ns_{rp,m,i}, & k_{s,r,f,i}, & k_{s,r,m,i}, & k_{s,na,f,i}, & k_{s,na,m,i}, & 0 \\ 0 & 0 & k_{k,hs,m,i}, & k_{k,hd,m,i}, & k_{k,rp,m,i}, & k_{k,r,f,i}, & k_{k,r,m,i}, & k_{k,na,f,i}, & k_{k,na,m,i}, & 0 \\ k_{i,u,i}, & k_{i,d,i}, & k_{i,hs,m,i}, & k_{i,hd,m,i}, & k_{i,rp,m,i}, & k_{i,r,f,i}, & k_{i,r,m,i}, & k_{i,na,f,i}, & k_{i,na,m,i}, & 0 \end{bmatrix} \quad (11)$$

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

Each element of *TM* is consequently evaluated based on the detailed knowledge of the particular telematic and communications configuration and its appearance probability in context of whole system dynamics. This approach so represents subsequent iterative process leading to stage, where all minor relations (indicators) are eliminated and the major coefficients of *TM* are identified under condition that all related telematic performance indicator are kept within given tolerance range. Four steps of the process leading to the final stage are:

[I] *primary elimination* of communication parameter based on implementation of relevant communication solution or setting (e.g. guaranteed homogenous radio signal coverage in defined area – e.g. airport runways, aircrafts rolling corridors etc),

[II] *primary disregarding* of communications 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] *final iterative identification of dominant indicators* as the last step of the iterative process of the *TM* identification is based on the virtual communication solution parameters settings. Potential solution modification can, however, lead identification process back to step *[I]*.

Presented method is discussed in [7] or [8]. Method is designed with clear aim to let user to cover the widest range of telematic solutions and for CALM standards based solutions criteria identification, as well.

2.3 Communications solution for ITS

Most of ITS serve moving objects, so that mostly appropriate wireless access solution is needed. There are typically applied DTMF (Dual-tone multi-Frequency), CSD (Circuit Switched Data), HSCSD (High Speed CSD), SMS (Short Message Service), USSD (Unstructured Supplementary Service Data), UUS (User to User Signaling) served via widely spread GSM (Global System for Mobile Communications networks). GSM mobile providers, however, preferably offer GPRS (General Packet Radio Service) and EDGE (Enhanced Data rates for GSM Evolution) data services. In area growing UMTS (Universal Mobile Tele-communications System) data services, are becoming available, as well. GSM and UMTS data services performance indicators are noticeably limited to let apply such wireless access services particularly for specialized “sensitive” ITS applications quantified by performance indicators.

Carrier grade mobile wireless communications solutions Mobile WiMax, i.e. communications system based on IEEE Std. 802.16d and Amendment 802.16e is promising system, which will be able to meet even very specific wireless access performance indicators requirements. However, Mobile WiMax has not been for the meantime available in certified version. In a short term Mobile view WiMax be mostly available only in dedicated installations, only. Nevertheless, expected reasonable value/cost ratio gives to Mobile WiMax in mid-term view potential to be successful in competition with UMTS. These expectations strengthen much more visible activities of companies like Intel, Nokia (NSN), Samsung and Motorola in IEEE 802.16 working group.

IP communications have gained for highly demanding solutions series of effective tools both on either L2 or L3 of the TCP/IP model. MPLS is understood as the L3 solution leader. However, L3/L2 switching (IEEE 802.3, 802.1d and 802.1q in latest versions applied on L2) is archiving remarkable position in ITS, namely due to remarkably faster network convergence and reasonable value/cost ratio. ITS solution needs usually to combine both mobile access and terrestrial backbone services and theirs simple transparent interoperability on L2 represents another crucial advantage.

2.4 Multi-path access solution based on CALM and L3/L2 switching.

Family of standards ISO 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) 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.

Typically applied 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 or redundancy of applied cannel coding. Goal of processes on this layer is to keep given set of managed parameters like Bit Error Rate (BER) or Round Trip Delay (RTD) within required limits.
- 2-nd layer – the first generation of handover (1HL) - represents support of process of the seamless switching between different cells of the same provider 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 only on identification of the service performance indicators due to fact that cellular systems are not usually designed as the open systems with appropriate application interfaces (API). Typically there is not mostly available interconnection with management of introduced model lower layers. The effective management on the 2HL layer would be easier reached if 1HL and LC layers share relevant information with managed layer 2HL. However, most of second generation handover decisions processes must be due to mentioned reasons designed based on fact that information from the lower layers will not be typically available.

Communications solution used in transport telematics potentially supported by CALM or alternative solutions are:

- *Cellular systems including 2G and 2.5G GSM and UMTS,*
- *RC (5.8GHz) used worldwide for road tolling and access control,*
- *Millimeter wave technology (62-63GHz) used in conjunction with radar signal at similar frequencies,*
- *Satellite communications exclusively applied for emergency and “special ap-plications”,*
- *Mobile Wireless Broadband (MWB) with cell usually much larger than UMTS cells – today namely communications systems based on IEEE Std. 802.16e and coming IEEE Std. 802.20,*
- *IR (Infra Read) communications solutions,*
- *WiFi (IEEE 802.11 based) different alternatives - a, b, g, n,*
- *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.*

CALM standard resolves alternative access path switching by vertical system de-composition to the individual subsystems for each communications access solution, however, management remains exclusively in the horizontal layers architecture mostly represented by API (API issue discussed e.g. in 15]). Relevant information needed for qualified decisions (incl. potentially of those from layers 1HL and CL) are between layers shared exclusively via the control system structures. Details of CALM architecture are described e.g. in [16] - [18]. CALM applies exclusively still not widely enough spread IPv6 protocol which allows due to its extensive abilities to continuously remotely trace active applied alternative. Handover is in CALM accomplished exclusively on the L2 of the TCP(UDP)/IP model, i.e. out of TCP/IP competences. Handover competences given to this L2 is suitable alternative for most of the wireless solutions and it opens possibilities to the non-TCP/IP based technologies like ZigBee or Bluetooth.

As a response on an acceptable solution urgent need authors proposed alternative approach based on L3/L2 TCP/IP switching operated in specific configuration and settings. This solution is understood as the only interim and in functionality limited substitution, however, with much less demanding and so faster implementation.

Decision processes are not discussed as frequently as it is with switching structures, even though implementation of the effective decision processes represents definitely the core of the issue. Due to lack of communication abilities between managerial centers of the lower layers (usually closed system) and the 3-layer of the adaptive communication access system management decision of the top layer must be usually done based on insufficient or no information available from the lower layers. Mostly the only "macro" performance indicators of the whole communication chain are available. That is why authors concentrate afford on this area. One of potential approaches to the decision processes is studied by authors and it is based on following principles:

- 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 or economical parameter.
- Final set of data lines parameters vectors represent basis for decision process (see e.g. [19] - [21]). The best path selection algorithm process available "cleaned" statistical data combined with the deterministic ones and decides based on "historical" training experience continuously improved by simultaneously processed self-training – see [22] - [23]. In the initial stage "minimal" high quality training data must be available for the first decisions.

Due to self-training approach proposed solution does not strictly require 2HL layer communication with the other layers. Nevertheless, it would be more efficient solution if such communication between layers is at least partially available in future implementations.

2.5 CaMNA communications design

Applied transformation method identified telematic performance indicator "accuracy" as the dominant indicator. This dominance is caused by real-time character of the CAMNA application installed in the specific conditions of airport area. Requested level of accuracy (see Table 1) must be reached for every object moving with speed up to 120km/hour. In this case within 200ms vehicle moves approx. 6.67m. There so remains demand on 0.83m accuracy of the GNSS sensor. This accuracy will be reachable by selection of Galileo services. For present-days tests based on the GPS sensors requested accuracy can be reached only if the differential GPS method is applied. All the other limits defined in Table 1 are met if total reached delay is below critical 200ms.

Delay limit of 200ms represent critical issue for the communications chain and it must be carefully kept namely in the airport critical areas (i.e. Class 1 areas like runways areas). This parameter considerably determines the communications chain performance indicators with consequences of elimination of most of available wireless communications solutions.

All the other limits defined in Table 1 are met if total reached delay is below critical 200ms. Delay limit of 200ms represent, nevertheless, critical issue for the communications chain and it must be carefully kept namely in the airport critical areas - i.e. Class 1 areas like runways and their surroundings. This parameter considerably determines the communications chain performance indicators with consequences of elimination of most of available wireless communications solutions.

Mobile WiMax (IEEE Std. 802.16e) was identified as the only possible alternative of the wireless access solution for critical areas of the airport. All the other available access systems like DTMF, CSD, HSCSD were identified as inappropriate. Also GPRS and EDGE as well as in area growing UMTS data services served by public GSM operators do not meet system requirements for the critical airport areas (200ms total max. delay of the whole communication system).

Even though Mobile WiMax was selected as the core mobile access system for the airport critical areas, whole airport area coverage with this technology is hardly reachable. Some of alternative access solutions (EDGE/GPRS/UMTS or even WiFi) for Mobile WiMax difficult areas can be applied, if system parameters of these technologies meet these areas system parameters requirements (Class 2 and lower) . For such case already discussed CALM access management is identified as appropriate tool.

L3/L2 switching (IEEE 802.3, 802.1d and 802.1q on L2) in combination with HW redundancy switching system "HYPER ring" (available proprietary solution produced by company Hirschman) was selected due to reachable values of the performance indicator MTTR (incl. convergence procedure below 100ms for 1Gb/s Ethernet ring) as well as due to transparent possibility to effectively interconnect fix and mobile solutions.

Introduces mobile and fix communication chain offers relevant communications system parameters in context of required by project performance indicators.

3. Results of CaMNA pilot project tests

The main goal of the pilot project communications system tests was to identify parameters of the Wimax wireless access solution integrated into CaMNA system.

Because of any certified Mobile WiMax systems based on IEEE Std. 802.16e has not been commercially available, the only possibility was to process test with implemented communication solution based on IEEE Std. 802.16d. This applied standard, however, offers the only limited achievable dynamic parameters.

Figure 2. OBU screen in vehicle (pilot test)

Airport area with the heaviest traffic was selected for pilot tests. This area also included runways with majority of traffic. Selected area was covered by one WiMax cell. Limits in dynamic processes given namely by applied smart antenna were taken in account in the pilot test design. Figure 2 typical screen-view, which also include additional information from airport management and Figure 3 CaMNA screen within other managerial screens in the pilot installation.

Figure 3. Dipatcher's screens (pilot test, only)

Due to limits given by applied technology (IEEE 802.16d compatibility and smart antenna designed for static application, only) most of tests were processed in the static regime. Obtained communications system static parameters are displayed in Table 2.
Both measurements were done in static regime. Sporadic packet re-transmitting controlled by applied TCP of the TCP/IP system is most probably caused by occasional interaction between WiMax radio and airport radars systems. Probability of packet delay exceeding 100ms is below required limit, i.e. .1%.

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

Table 2. – principle parameters of the WiMax access

where LFR means "Lost Frames Ratio", ART "Average Round Trip" and SNR "Signal to Noise Ratio".
Spectra of Round Trip Delay (RTD) in ms are displayed for LOS (Line Of Sight) configuration on Fig. 4 and for NLOS (Non LOS) alternative on Fig. 5.

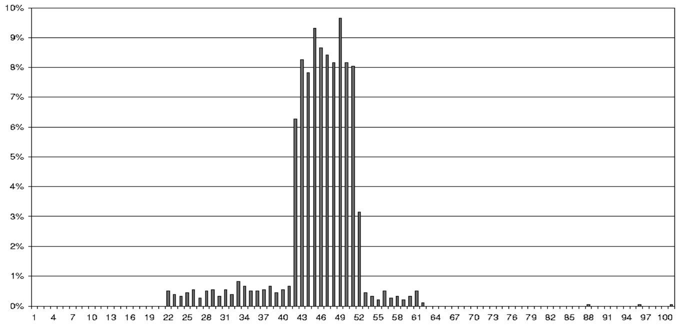

Figure 4. RTD spectra of LOS Site 2

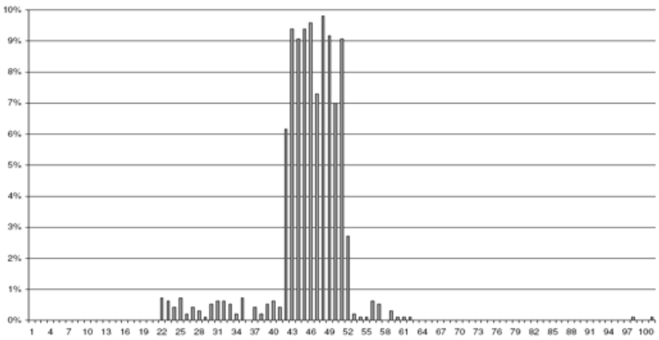

Figure 5. RTD spectra of NLOS Site 3

Test with moving vehicles were operated only in the "open area", where switching between LOS and NLOS regime frequently accompanied with new setting of the smart antenna is not expectable. Dynamic parameters of applied smart antenna were dominant blocking dynamic processes parameters experimental analysis. Dynamic parameters of the WiMax internal processes extended with handover times will be tested immediately certified Mobile Wimax, (system based on Appendinx IEEE 802.16e Std.) is available. Motion tolerance up to expected 100km/hour was identified (in "open" area) on required probability level even with IEEE 80.16d based system.
Results confirmed, that critical dominant performance indicator, i.e. round trip delay, meets calculated requirements under accepted restrictions given by applied technology. Reached mobile part results give appropriate space (more than 100ms on probability level

of 99.9%) to the terrestrial solution. It is reachable requirement on terrestrial backbone network based on HW switched Ethernet rings, like it is e.g. in case of HYPER ring.

Final solution covering the whole airport area will, evidently require cellular architecture, i.e. Mobile Wimax (IEEE Std. 802.16e based certified system) combined with alternative access solutions, if it is appropriate and effective (Class 2 and lower like depot areas). Such combination calls due to economical reason for final solution based on application of the second generation of handover in the cellular structure, i.e. management system based on either CALM family of standards or alternative solution with implemented effective and safe decision processes [22] and [23].

4. Conclusion

Airport pilot project represents typical ITS, where correct communication solution identification and its parameters settings play crucial role. The main goal of this paper is to introduce method for effective design of communication solution dedicated for specific telematic system based on each subject position identification and distribution of this information within relevant group of users incl. the other moving objects – see [7] to [11].

Most of available communications wireless access solution like GPRS, EDGE, or UMTS are noticeably limited in performance indicators (UMTS also in covered areas) to let employ such wireless access services for “sensitive” ITS applications like the one represented by introduce system operated on the strictly regulated airport area (namely sensive areas of Class 1).

Mobile WiMax solution (IEEE 802.16e) represents ”carrier class” wireless access solution with performance indicators meeting requirements even in most strict parts of the airport area. Due to fact, that Mobile WiMax has not been to date available in certified version we can expect that only in mid-term view remarkable advantages of this technology (cost, convergence, CoS management) will lead Mobile WiMax to position of important widely spread publicly available competitor to UMTS and GSM. Due to ability to provide efficient and transparent control of service quality (QoS) Mobile WiMax is understood as very promising access technology in wide range of ITS applications.

Introduced method of selection and configuration of the communications solution for telematic application based on identification of the transformation matrix *TM* between communications and telematic performance indicators vectors was presented and demonstrated within airport project for specific communications solution design. Mainly due to real-time character of the application and potential high speed of moving objects (incl. landing and taking off aircrafts) telematic performance indicator “accuracy” was identified as the dominant telematic indicator. Required accuracy must be in areas of Class 1 unconditionally reached for every moving object. Based on identified transformation matrix *TM* communication delay limit is identified as the critical communications performance indicator and all performance indicators limits are reached if the overall delay of the communications chain is kept below critical 200ms on probability level of 99.9%.

This limit represents the essential issue for the communications solution and it determines selection and setup of the communications chain. Principal delay limit must be, however, carefully respected only in the airport critical areas - Class 1, i.e. namely runways and their surroundings. In these areas e.g. probability of handover would be reduced by signal coverage topology to minimum.

Results of applied method expectably disqualified such communications “gurus” like MPLS backbone terrestrial networking or GPRS/EDGE wireless access as potential core technologies due to fact, that these communications systems cannot guarantee critical areas airport performance indicators limits definitely for Class 1 areas. Combination of the Mobile WiMax (IEEE Std. 802.16e) as core access service and terrestrial L3/L2 switching solution combined with HW redundancy switching system was selected. One of potential already available alternatives “HYPER ring” system has been already applied for other airport area control system purposes, so that choice was very simple.

Selected core “carrier grade” WiMax access solution is combined with alternative access technologies, where it is quantified as the relevant approach (Class 2 and lower). Switching between access services is processed by system based on CALM standards or its mutations like e.g. L3/L2 specifically configured switching solution. Success of such approach is, however, dependent on correct implementation of the effective decision processes. In L3/L2 alternative due to lack of communication abilities between managerial centers of the lower layers with the 3-rd layer management of the 3 layer adaptive communication access system decision on the top layer must be usually done based on insufficient or even no information available from these lower layers. Mostly the only “macro” performance indicators of the whole communication chain are available. The main ideas of developed decision processes were presented and self-training approach applied on by Kalman filters processed data is identified as the promising alternative.

5. References

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

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

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

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

[7] Zelinka, T. Svítek, M.: 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] Zelinka, T. Svítek, M.: Communications Enviromnent for Telematic Subsystems, Proceedings of 11-th World Multi-Conference on Systemics, 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] Svitek, M., Zelinka,T.: Communications Challenges of the Airport Overgroud Traffic Management. Proceedings of the 11th WSEAS ICoC, pp. 228 – 234, Agion Nikolaos, Crete Island, Greece, ISSN 1790-5117, ISBN 978-969-8457-91-1.

[10] Svitek, M., Zelinka,T.: 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] Zelinka,T., Svítek, M.: Localization Performance for ITS Applications, Proceedings of International Conference TRANSTEC Prague, Czech Technical University, Faculty of Transport Science and University of California, Santa Barbara, Praha 2007, pp.119 – 123, ISBN 978-80-0-03782-9

[12] Zelinka,T., Svítek, M.: 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.

[13] Svitek, M., Zelinka, T.: Monitoring of Transport Means on Airport Surface, Proceedings of 7-th International Conference on Transport Systems Telematics, Katovice-Ustron, 2007, pp. 285 – 292, ISBN 978-83-917156-7-3.

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

[15] Beheshiti, B. D.: Reconfigurable Wireless Handset Realization Based on Universal API, Proceedings of the 11th WSEAS IMoC, , pp. 361 – 365, Agion Greece, ISSN 1790-5117, ISBN 978-969-8457-91-1.

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

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

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

[19] Swamy, B. K., Kulkarni, P. A.: Intelligent Decission Making Based Clustering and Classification Mind-Maps, WSEAS Transactions on Business and Economics Issue 4 (2006), Vol. 3, pp 379 – 385, Athens 2006, ISSN 1109-9526,

[20] Portilla-Figueras, A., Salcedo-Sanz, S., Garcia-Diaz, P., Hackbarth, K.: Meta Heuristics Algorithm applied to Economic Mechanisms for Efficient Scarce Resources Allocation in Communication Networks, WSEAS Transactions on systems, Issue 3, Volume 5, Athens, pp. 474 – 480, ISSN: 1109-27774 (2006).

[21] Svitek, M.: 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.

[22] Svitek, M., Zelinka, T.: Communications multi-path access decision scheme, Neural Network World, ICS AS CR and CTU, FTS, Praha, 2008, ISSN 1210 0552 (in print)

[23] Zelinka, T., Svitek, M.: Decision processes in telematic multi-path communications access systems, International Journal of Communications, North Atlantic University Network (NAUN), Issue 2, Volume 1, 2007, pp.11 – 16, ISSN: 1109-9577.