Transport system architecture for on board wireless secured A/V surveillance and sensing

C. Lamy-Bergot, *Senior Member, IEEE,* S. Ambellouis, L. Khoudour, D. Sanz, N. Malouch, A. Hocquard, J-L. Bruyelle, L. Petit, A. Cappa, A. Barro, E. Villalta, G. Jeney and K. Egedy

***Abstract*—This paper describes the system architecture set up by the consortium of the EUREKA CELTIC BOSS project for enhancing the security of passengers inside commuter trains. The functional approach, together with obtained technical improvements in the three domains of wireless communications, abnormal events detection and video compression and robustness enhancement are presented. The demonstrator set up in the project, which was installed in a real commuter train in commercial operation, is also reported as proof-of-concept.**

***Index Terms*—Rail transportation, Wireless communications, interconnected systems, Routing and Transport Protocols, Video signal processing**

I. Introduction

IMPROVING security of public transport systems is a key problem that has been mobilizing operating companies since many years. To make their systems safer and more attractive, the operators have deployed widely video surveillance tools for grabbing images either outdoors (stations entrances, platforms, *etc.*) or indoors (stations, corridors, carriages, *etc.*). These applications are usually made for "remote" viewing or recording (in particular from mobile elements such as bus or trains). The cameras are usually connected to a control room (PCC) where an operator will detect any abnormal event and then launch the adequate procedure. Because of the increasingly number of CCTV cameras, the monitoring task requires always more from the operator to maintain a short reaction time and a high level of security. Furthermore, the increasing demand for on-board mobile surveillance units, pushed by the end-users and public authorities [1][2], implies the use of wireless communications systems to transmit the video surveillance streams. In this context, it is important to develop automated tools to first assist the monitoring task in the control room but also help discriminate which streams should be transmitted in priority on the ever bandwidth limited wireless links. Thanks to this technical approach, the operator will not need anymore to control all screens all the time, and the wireless bandwidth will be used to carry abnormal streams with high quality.

First solutions for aided video analysis were for instance proposed in the context of PRISMATICA project [3] where “intelligent cameras” connected to a supervision module were able to compute analysis such as intrusions in forbidden areas, queuing, loitering, objects left. Similarly, solutions for efficient radio resources management in sub-urban context, with 802.16 standard evolutions have been proposed in the context of EVAS project [4]. However, the issue of overall end-to-end Quality of Service (QoS) solutions design for enhanced user safety is still open, and the corresponding attuning of the different elements of the transmission chain. Following discussions with the French and Spanish national train operators (SNCF and RENFE), partially motivated by their respective public authorities reports [5], the BOSS project has been launched by France, Spain, Belgium and Hungary in the framework of Eureka CELTIC cluster to study and propose a communication system allowing the deployment of a security solution for passengers against attacks/crisis and for preventive maintenance for the rolling stock.

This paper is organized as follows: firstly the BOSS architecture is detailed, including the system level approach and summary of the specific technical improvements obtained within the project in the three domains of link efficiency, event detection solutions and multimedia data processing. Then, the demonstrator built in the project as a proof-of-concept is presented, followed by examples of obtained results. Finally, some conclusions are drawn.

II. BOSS Architecture

A. System level approach

The BOSS project has been developing a communication system relying on an IP gateway placed inside the train to enable the communications both inside the train, for communications inside carriages and for mobile passengers and controllers (*e.g.* with WiFi links), and outside the train,

The work presented in this paper was partially sponsored by national French, Spanish, Belgian and Hungarian funds under the auspices of EUREKA CELTIC BOSS project.

C. Lamy-Bergot is with THALES Communications S.A., EDS/SPM department, 160 boulevard de Valmy, BP 92, F-92704 Colombes (e-mail: catherine.lamy-bergot@ fr.thalesgroup.com).

S. Ambellouis and L. Khoudour are with Institut National de Recherche sur les Transports et leur Sécurité (INRETS), France. D. Sanz is with Société Nationale des Chemins de fer Français (SNCF), France. N. Malouch is with Université Pierre et Marie Curie, France. A. Hocquard is with Alstom-Transport, France. J-L. Bruyelle is with Université catholique de Louvain (UCL), Belgium. L. Petit is with BARCO-SILEX, Belgium. A. Cappa is with Telefonica Investigacion y Desarrollo, Spain. A. Barro is with Arteixo Telecom, Spain. E. Villalta is with Ingeniería y Economía del Transporte (INECO), Spain. G. Jeney is with Budapest University of Technology and Economics, Hungary. K. Egedy is with E-GROUP Ltd, Hungary.

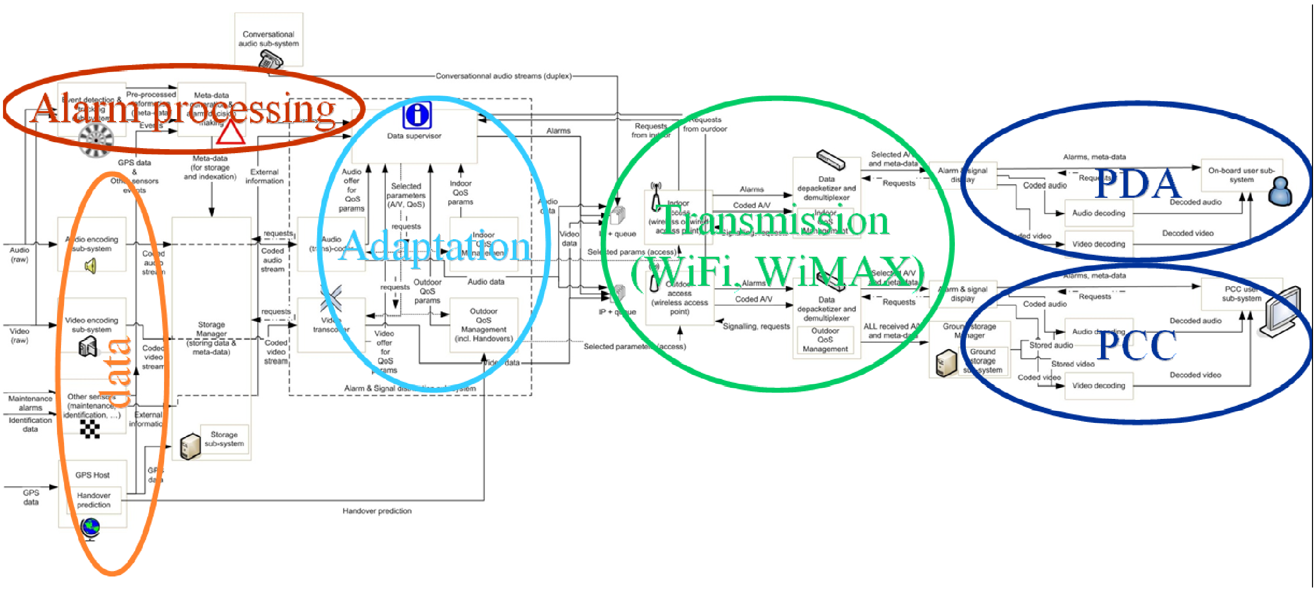

Fig. 1. BOSS detailed functional architecture: from data capture to its destination inside and outside the train.

mobile in the terrestrial reference frame, with a link towards wireless base stations (*e.g.* WiMAX, HSUPA links).

Due to the bandwidth limitations in wireless communications, and the large amount of data generated by a set of surveillance cameras, hardly manageable by an operator, a fair share of the BOSS technical work was done on video surveillance applications adaptation, to improve behavior analysis and audio processing tools for abnormal events detection. To generalize the approach, specific sensors have also been introduced, in order to detect events such as temperature, doors opening, …

Figure 1 presents the overall BOSS system functional architecture, from data acquisition (on the left) to the destination display on controller PDA or operator PCC (on the right), with alarm processing in-between, adaptation to the transmission conditions (including intelligent transcoding of the video stream for best perceived video quality at the reception) and transmission over the mobile IP links.

B. Wireless link efficiency

For the connection between the train and the PCC, a commercial equipment based solution was developed, relying on WiMAX and UMTS connections. This dual wireless link was organized to offer with the UMTS connectivity a back-up limited but guaranteed throughput in non covered WiMAX areas. This dual link was studied to ensure efficient horizontal and vertical handover management, to avoid impacting the end-to-end Quality of Service for the end-user. Furthermore, in order to evaluate the possibilities to increase this outdoor link efficiency, the WiMAX-like MIMO extension introduced in [4] was further improved with introduction of a feedback link for wireless link quality monitoring and adaptive transmission for train to ground communication.

Wireless Sensor Networks (WSN) were also considered to increase indoor coverage, as is further detailed in [6].

C. Data acquisition and event detection solutions

Facing the observation that the complete set of data acquired in a train could not be transmitted in full resolution to the way-side, due to the limitation of the wireless link, but also the fact operators facing many camera displays will need help to focus on the most problematic ones, we have introduced abnormal event detection tools inside the train. With our system, only data corresponding to detected events (so called alarms) or data explicitly requested by the operator are transmitted from the train to the control centre. Nevertheless, to offer the possibility of performing post-processing on the acquired data, and to fulfill the legal requirements on the recording of surveillance cameras, a storage unit has been introduced in the system that stores all data as well as the results of the analysis carried (events detected). For better service offer, this storage manager was also doted of the capacity to transmit data from previous instants, allowing typically the operator to request images or sounds from moments before an alarm is detected.

As previously mentioned, different data sources have been considered, to ensure a variety of services (from fire alarm and door opening detection with sensors to audio detection of paint bombs or video display) as well as validate the generality of the system.

D. Multimedia data processing with enhanced robustness

The main challenge in the data transmission was to ensure a good reception of the video streams, which represented more than 90% of the bitrate to be transmitted. The well-known high sensitivity of video streams to errors and losses, and the necessity to operate in a bandwidth limited context lead us to use the state-of-the-art finest compression algorithm (H.264 AVC and SVC standard), and to enhance its robustness thanks to error correction insertion. This would have been insufficient

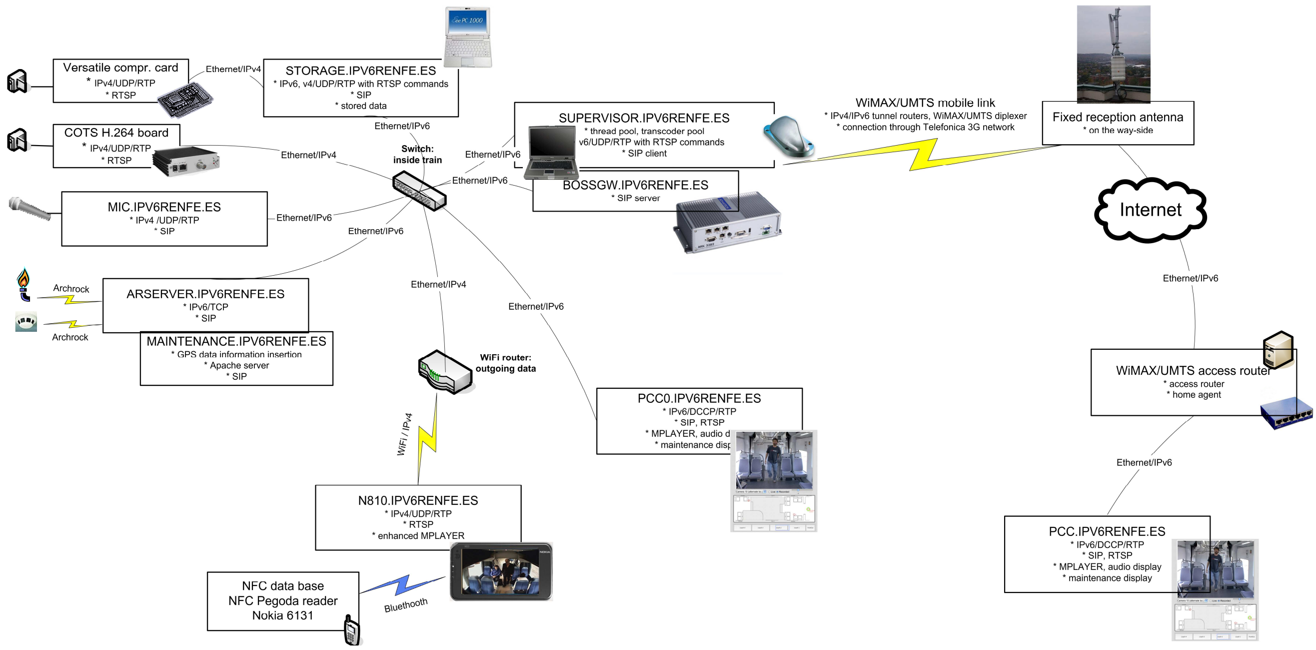

Fig. 2. BOSS demonstrator organization: detailing each module role and realization key elements.

in the highly varying context of a mobile transmission of a changing number of sources, so an adaptation stage, realizing the protection insertion as well as transcoding to decimate the stream when needed were added. More details on this adaptation module, together with information on the possible usage of advanced transport protocols such as DCCP (Data Congestion Control Protocol) can be found in [7].

III. Demonstrator set-up

In order to validate the BOSS project architecture, as well as the principle of intelligent transmission from rolling equipment, a demonstrator was developed. This was done following a two-level approach, resulting into first a “lab” demonstrator, and secondly a “full” demonstrator. The lab demonstrator had a particular focus on the audio, video and alarms distribution and the data supervision as its objective was to validate the multi-sources transmission, with adaptation to the channel limitations and impairments … but without the actual train environment constraints (no or slow motion conditions), while in the mean time UMTS and WiMAX transmissions were tested with a car. The full demonstrator corresponded to the insertion of the lab system and UMTS/WiMAX transmission into a real train.

Due to the necessity to validate the transmission on sequences with events such as aggressions, cameras displacement or shouts, and the will to limit the impact on the actual passengers in the demonstration train, it was decided to introduce in the system an emulated carriage, were events would appear regularly. Those events were generated from realistic data acquired in a first trial phase in RENFE trains done in March 2008. The emulated carriage, allowing to insert events without disrupting the proper train operation, relied on the presence in the train of the storage unit (called the storage manager) which was able to deliver pre-stored sequence time shifted to current time to emulate the presence of a set of cameras and compression cards providing compressed H.264 streams with corresponding events pre-determined off-line.

Figure 2 illustrates the demonstrator organization, and details the role of the different modules or equipment present. On the left hand, is depicted the train network, which contains the data acquisition, event detection and adaptation parts, and on the right hand is presented the control centre part, where the operator would be observing the transmitted data. As proposed in the functional architecture, the presence of a controller inside the train is also considered, who will receive alarms and data on its Nokia N810 PDA.

IV. Field trials

As stated in the previous section, a first field campaign has been carried out in April 2008, during which audio/video acquisitions of different events played by team actors have been performed in a moving train. The corresponding database was used to validate and calibrate our events detection algorithms, such as people tracking, audio detection, and so on. These sequences are now available to the research community for further usage.

A second campaign was carried out in April 2009 in a RENFE Civia train in commercial usage on the Chamartin-Aranjuez Cercanias line. This trial allowed to validate the BOSS approach and to demonstrate to train operators the capability of the proposed system. A third campaign was done also in April and May 2009 to further validate the wireless link transmission part. We present hereafter a focus on the results obtained for the link transmission as well as functionality validation for video transmission. Full details on this demonstration can be found in [8].

A. UMTS/WiMAX wireless links validation

Due to the limited time of access in the rolling train, the majority of the wireless links measurements were conducted with a car, and referred in the following as “car scenario”. Nevertheless measurements were also conducted within the RENFE train. In the following, only the uplink traffic measures are reported, as they correspond to the train to ground link which is of interest in the BOSS context.

In the car scenario, a moving car in North Madrid area with a laptop connected via an HSDPA UMTS router (UMTS MoviStar network of Telefónica) As defined in the High Speed Downlink Packet Access (HSDPA) standard, the upload theoretical traffic capacity is limited to 384 kbps. The UMTS network does not offer native IPv6, so an IPv6 tunnel was set up in the performed tests. Similar tests were done with the WiMAX router.

In the train scenario, the UMTS router was placed in the train on the Chamartin-Aranjuez line, but the WiMAX could not be used due to last minute impairments. As a consequence, the train scenario was reduced to the IPv4 context with UMTS connectivity.

1) Car scenario

In the car scenario, the main objective was to measure the limitations of the UMTS and WiMAX links in terms of coverage and throughput. As a consequence, we used a UDP packets generator to transmit data and measured the received throughput to be compared to a transmitted rate greater than the 384 kbps limit. Figure 3 presents the UMTS coverage, with the track depicted by a blue line, green balls placed in the areas with more than 200 kbps of traffic received at the control centre, yellow balls for areas where than 100 kbps were received and red balls in areas were less than 100 kbps were obtained. Additionally, black arrows represent handovers in the trip.

It can first be observed that the UMTS coverage is generally good enough (more than -80dBm) to reach the target 200 kbps throughput in this North Madrid area, even with car speed up to 120 km/h and the presence of buildings. Handovers are as expected affecting the data transmission, but are recovered quite quickly, and the IP connection was not lost during the test, allowing to keep the IPv6 tunnel working.

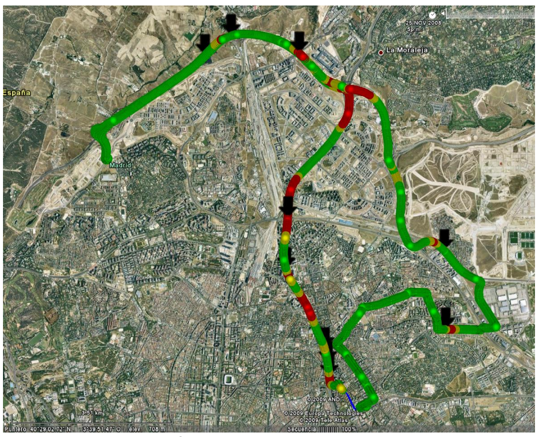

Fig. 3. Visual illustration of the UMTS car scenario coverage.

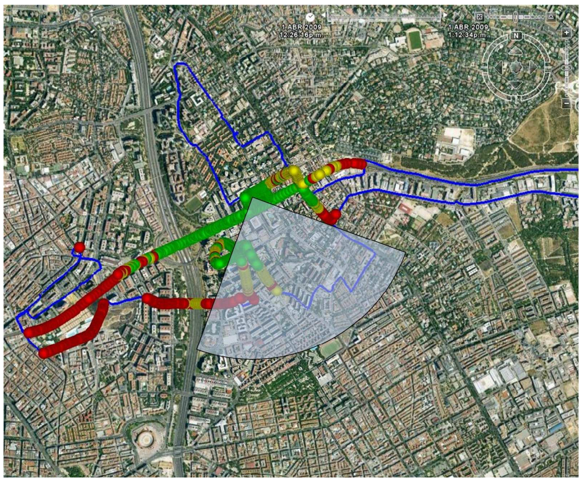

Fig. 4. Visual illustration of the WiMAX car scenario coverage (case A).

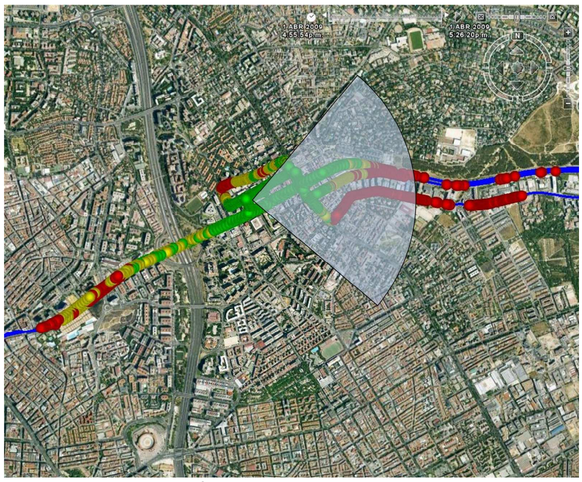

Fig. 5. Visual illustration of the WiMAX car scenario coverage (case B).

With the WiMAX router and again the car scenario, the UDP packets were transmitted from the laptop in the car at a rate greater than the best available WiMAX modulation (1.8 Mbps), and the reception throughput rate was again measured, with two different antenna coverage realizations (case A and B as depicted in the Figures 4 and 5). In those two Figures, the received throughput is again illustrated by green balls for more than 1 Mbps traffic received, yellow balls for more than 500 kbps traffic received and red balls for less than 500 kbps received, with no balls only when no traffic at all was observed. In this case, a unique base station is used, so no handover can happen. It is to be noted that this traffic is obtained thanks to the WiMAX router getting again the same IP address when recovering connectivity, which allowed the IP tunnel to work again.

It can be observed that the WiMAX coverage is affected by the obstacles as buildings, as loosing line of sight rapidly degrades the signal (case B coverage is slightly better due to less obstacles with this antenna orientation). On the other hand, although the base station antenna is only specified as a 90 degrees angle, a good coverage is also obtained for greater angles, and even sometimes near or behind the base station.

The observed WiMAX coverage is two kilometers long. Similarly to the UMTS case, the car speed (going up to 120 km/h) did not impair the transmission.

2) Train scenario

The various tests done with the train scenario test (UMTS only) let us conclude that the UMTS radio repeater is a critical element in order to have good quality radio signal inside the train. In all the tests conducted, no coverage problems was experienced, as in the car tests presented before.

Several measurements are presented in TABLE 1, that show that the receiver throughput was very good, as data traffic of 300 kbps went easily through while acceptable packet losses were observed. It is expected that with the future HSUPA (High Speed Uplink Packet Access) routers, which will authorize throughputs of more than 1 Mpbs, the efficiency of such an UMTS link would permit data transmission in BOSS like contexts.

B. Alarms, audio and video transmission validation

As an illustration of the video transmission validation is presented in Figure 6 an image grabbed from the PDA controller during the train demonstration in April 23th, 2009. This image was generated by the camera of the RENFE train, whose analog signal was encoded by an H.264/AVC encoder, resulting in a stream transcoded to the authorized bitrate of 256 kbps and sent by WiFi to the PDA.

TABLE I
TRAIN SCENARIO (UMTS TRANSMISSION)

Stream and position conditions characteristics	Estimated data rate including headers	Percentage of packet loss
Video stream with train stopped in Chamartin station, 157 s video time	333 kbps	5.93 %
Video stream with train moving, 157 s video time	314 kbps	6.44%
Video stream with train moving and additional reduced camera movement, 622 s video time	208 kbps	10.78 %

Similarly, audio transmission and event detection was validated, considering the use case of bomb paint detection, and the transmission of events from temperature sensors was observed.

Fig. 6. Grabbed images from live sequences transmitted to the controller PDA during train demonstration.

V. CONCLUSIONS

The very good reception of the demonstration by the different people having attended it, whether train operators (SNCF, RENFE), train builders (ALSTOM), service providers over trains (THALES Transport Systems), and telecommunications operators (Telefonica Moviles, Telefonica Corporate), as well as the results obtained and detailed in the project deliverables (see also [8]) are letting the authors believe that proof-of-concept they aimed at building was a success and that the road to adaptive surveillance on the move is now opened for actual product realization.

ACKNOWLEDGMENT

The authors gratefully acknowledge their colleagues from the EUREKA CELTIC BOSS project for their technical contributions and support through the project life, and RENFE who provided several times a train for evaluation purposes.

REFERENCES

[1] Préfecture de police de Paris, “Service Régional de Police des Transports de la Préfecture de Police”, March 2005. Available : http://www.prefecture-police-paris.interieur.gouv.fr/documentation/dossiers/SRPT.pdf

[2] European Commission, “White paper: European transport policy for 2010: time to decide”, September 2001. Available: http://www.eurosfaire.prd.fr/7pc/doc/1131022490_livre_blanc_politique_transports_2010.pdf

[3] S.A. Velastin, L. Khoudour, B.P.L. Lo, J. Sun and M.A. Vicencio-Silva, “PRISMATICA: a multi-sensor surveillance system for public transport networks”, Proc. of IEE RTIC 2004, pp. 19-25, April 2004.

[4] G. Moniak, E. Masson, H. Dumortier, M. Berbineau and A. Rivenq, “Robust and High Data Rate Wireless Link for Security Between a Bus and a Control Centre”, Proc. of IEEE VTC-2007 Fall, pp. 1426-1430, Sept-Oct. 2007.

[5] IAU (Institut d’aménagement urbain), “note rapide n°418 : sécurité et comportement”, October 2006. Available: http://www.iaurif.org/fileadmin/Etudes/etude_222/nr_418_CDS_dans_les_TC_idf.pdf

[6] O. Gatin, N. Malouch and A. Barro, “Wireless mesh and sensor networking for onboard detection and video alarm transmission for BOSS project”, Proc. of ITS-T 2009, Lille, France, Oct. 2009.

[7] C. Lamy-Bergot, E. Renan, B. Gadat and D. Lavaux, “Data supervision for adaptively transcoded video surveillance over wireless links”, Proc. of ITS-T 2009, Lille, France, Oct. 2009.

[8] BOSS project, “Deliverable D4.4: BOSS final trial results report”, May 2009. A public excerpt (film) is available at http://www.celtic-boss.org