Communications Challenges in the Celtic-BOSS Project

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Abstract. The BOSS project [1] aims at developing an *innovative and bandwidth efficient communication system* to transmit large data rate communications between public transport vehicles and the wayside to answer to the increasing need from Public Transport operators for new and/or enhanced on-board functionality and services, such as passenger security and exploitation such as remote diagnostic or predictive maintenance. As a matter of fact, security issues, traditionally covered in stations by means of video-surveillance are clearly lacking on-board trains, due to the absence of efficient transmission means from the train to a supervising control centre. Similarly, diagnostic or maintenance issues are generally handled when the train arrives in stations or during maintenance stops, which prevents proactive actions to be carried out. The aim of the project is to circumvent these limitations and offer a system level solution. This article focuses on the communication system challenges.

1 Introduction

The purpose of the BOSS project is to design, develop and validate an efficient railway communication system both on-board trains and between on-board and wayside with a guaranteed QoS (Quality of Service) level to support the high demands for services such as security on-board trains, predictive maintenance, as well as providing internet access or other information services to the travellers. The principle of the overall architecture proposed to meet this goal in given in Figure 1. Railway communications can be considered as highly challenging because of the specific environment (safety, speed up to 350 km/h, tunnels, low cost, etc.). Therefore, the results from the BOSS project will serve other application areas like road applications, The work in the BOSS project will focus on providing an optimised communication system relying on an IPv6 (Internet Protocol version 6) architecture for both on-board and wayside communications, that will offer a high QoS level to allow support of both the high demands for better passenger security on-board trains and the high throughputs and lower QoS for the travellers.

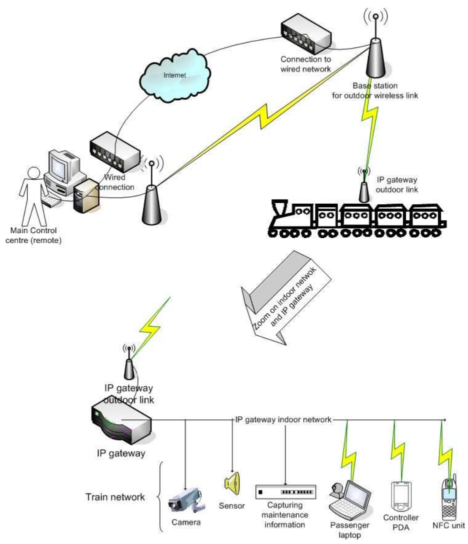

Fig. 1. The BOSS project architecture

The BOSS project will lead to the availability of validated new and/or enhanced passenger services such as passenger security, predictive maintenance and internet access on board public transport vehicles such as trains, through an efficient interconnection between land and on-board communication systems with a guaranteed level of QoS. Moreover, in order to validate the design but also integrate real requirements, the use of realistic specifications and the adaptation of simulations based on real life inputs, will be validated by the BOSS project through the implementation and the testing of two different transmitting techniques (typically among WLAN, WiMAX, UMTS or similar systems). This will demonstrate the wireless connection capability both for surveillance needs inside the carriages and from the train to the surveillance centre as well as for Internet access within the train. This technology platform will allow to demonstrate the feasibility of transport on-board surveillance, leading to the increase of the level of security services and comfort feeling in Public Transport for European citizens.

It should be noted that the reason why video applications are a key issue in the project is that the bandwidth they require is far from negligible, which will have a deep impact on the choice of wireless accesses and design of end-to-end QoS solutions, but also handover capabilities. Furthermore, video streams have to be transmitted simultaneously from several trains to the control center when alarms are set up. The problem of radio resources management and multi user accesses are also an important issue of the BOSS project.

To reach these goals, the following axes will be followed and investigated:

- establish interconnectivity between internal wired, internal wireless (e.g. WLAN) and external wireless (e.g. WiMAX, UMTS, 3GPP+, 802.22, . . .) systems, with handover issues on external wireless links, coverage and multi user issues,
- ensure guaranteed QoS, including while performing handovers, to allow for an end-to-end QoS over the whole system, manage the different QoS on the different data links,
- develop robust and efficient video coding tools that can be embedded in handheld devices and respect low delay requirements (for mobile supervisors use),
- propose video analysis solutions for security issues,
- provide audio processing tools to complement video and improve robustness of alarms generation.

This document focuses on the first two areas. Since the project was started in October 2006, and it is 2.5 years long, there are no specific results yet, which are worth mentioning. The primary aim of this publication is to receive opinion feedback from the scientific world about the way the project chose to follow.

2 State-of-the-art situation

2.1 State-of-the-art on dual mobility for transmission with QoS

Mobility over IP networks Mobile IPv6 (MIPv6) provides layer 3 transparent mobility for the higher layers (for example TCP), so a mobile node remains reachable with its home address without the need of being connected to its home network. The transition or handover between networks is transparent for the higher layers and the connectivity loss produced during the handover is due to the exchange of the corresponding signalling messages. Every Mobile Node (MN) has a local address (or Home Address), which represents its original network address. This address remains the same independently of the mobile node position, which when passing to another network still keeps its home address. Packets sent to the mobile node, when staying in its original network, will be routed normally as if the node was not mobile. The prefix of this address is the same as the network prefix where the node was originated. When a mobile node goes to a different network, it obtains a guest address (Care-of-Address, CoA), belonging to the address space of the visited network. The mobile node can acquire its care-of address through conventional IPv6 mechanisms, such as stateless or stateful auto-configuration. From now on, it can be reached also with this new address (apart from the home address). After obtaining the new address, the mobile node contacts a specific router from its home network (Home Agent, HA) and, during the registration process, the node registers its current CoA. Afterwards, when a packet is sent to the mobile node home address, the Home Agent will intercept it and tunnel it to the mobile node CoA. With this mechanism, the packets reach the mobile node at any location, because the CoA belongs to the address space of the subnet where it is connected.

Handovers over wireless systems Handover refers to the process of changing access points during communication. It can be divided into two separate parts, horizontal handover (HH) and vertical handover (VH). Horizontal handover means changing access points inside the same network, i.e. the user changes its geographic position and thus a new access point is assigned to maintain the communication link. For example, horizontal handover happens when a mobile service subscriber exits a cell and enters another. Vertical handover means changing between different technology access technologies (networks) which are available at the same geographic location without disturbing the communication. For instance, if both GSM/GPRS and UMTS networks are available, the user switches from GSM/GPRS to UMTS, typically in the hope of having higher bandwidth.

Another goal is toimplement IP based vertical handover protocols. With such protocols transparent mobility management might be realised (switching between access networks, roaming). An important scope of such protocols is the support of the multimedia streaming services spreading nowadays in mobile communication. The most serious problem is IP address changes caused by the handover. During the handover the mobile client roams to another access technology, and to another service provider at the same time ; after the handover a new IP address is assigned to it. The objective of the protocol is to hide the change of the address from upper layers both at the mobile device and at the communication partner. While we are focusing on TCP/UDP traffic, the protocol must handle the socket-pair on both sides to maintain the connection state.

End-to-end QoS over heterogeneous networks A special care will be taken to address end-to-end service continuity and QoS support across wired and ad hoc wireless networks. Providing Quality of Service to the network, especially in the case of several hops in a heterogeneous and dynamic environment is a challenging task. Static internet Quality of Service (QoS) solutions are difficult to implement in mobile ad hoc networks: The IntServ/RSVP architecture QoS model is not suitable due to the limited resources (e.g. the amount of state information increases dramatically with the number of flows and the nodes must perform admission control, classification and scheduling functions). The DiffServ architecture would seem a better solution. However, DiffServ is defined for a fixed infrastructure in which there are boundary DiffServ routers that perform QoS functions and a Service Level Agreement (SLA) that defines the kind of contract between the Internet Service Provider (ISP) and the client. In a mobile ad hoc network it may be difficult to identify what are the boundaries. A node should be able to work both as a boundary and as an interior router. That complicates the tasks of the nodes. Furthermore the very concept of SLA is also difficult to define in such environments. There are several proposals based on QoS aware routing and QoS aware MAC layer. However, QoS architectures and protocols still need to be studied further, especially with respect to node mobility, network diameter and processing power.

Transport protocols face major challenges for the end-to-end support of QoS in wired/wireless heterogeneous networks. The main transport protocol, TCP (Transmission Control Protocol), has been designed to provide reliable end-to-end data delivery. The mechanisms have been designed and tuned for wired networks and ignoring the specificities of the wireless medium, such as high bit error rates, frequent loss of connectivity, power constraints... Streaming applications, especially for audio and video, share a preference for timeliness over reliability. These applications tend to use RTP (Real Time Protocol) in place of TCP, to avoid the built-in congestion control mechanisms of TCP that lead to increased delay in the delivery of packets. The coexistence of congestion controlled traffic (TCP) and non congestion controlled traffic (RTP/UDP) on the same network induces a lack of fairness between the different sessions and thus poses severe challenges to the overall QoS architecture. The project will study this issue, will review the work carried out in the IETF group DCCP (the Datagram Congestion Control Protocol) and will propose specific congestion control mechanisms adapted for the BOSS heterogeneous wired/wireless mesh network.

The BOSS project will study and propose an end-to-end QoS framework that can apply both to fixed and ad hoc network extensions. The key features of this framework will comprise the definition of a QoS policy for the ad hoc and public safety world, in compliance with management and accounting rules, the identification, signalling and marking of flows to render a co-ordinated end to end service and the development of techniques for prioritising flows in each individual sub network.

QoS over IP networks In itself, QoS is an intuitive concept, defined by ITU-T Rec. E.800 as: "the collective effect of the service performance which determines the degree of satisfaction of a user of the service" or "a measure of how good a service is, as presented to the user, it is expressed in user understandable language and manifests itself in a number of parameters, all of which have either subjective or objective values." Even though these definitions are quite simple and comprehensive on a global level, it is generally complex to determine real measures to reflect specific network requirements or constraints. Furthermore, realising applications conforming to subjective parameters can be extremely difficult due to contrasting user needs.

For these reasons, standard organisations and network researchers have spent considerable efforts in order to map the end-user perspective to specific network requirements. The results essentially report a subjective opinion of a properly set of hypothetical and testing users with regards to the satisfaction of the service (for example the vision of a video or the listening of a recorded audio), that in turn depends on several aspects, in particular network related in a telecommunication scenario. ITU-T has defined in Rec. P.800 a Mean Opinion Score (MOS) scale, which can be used to map the subjective opinion score to a qualitative value.

New wireless solutions in mobility mode The current state of the mobile communication and consumer electronics can be characterized by the convergence of devices and by the growing needs for connecting those devices. In this last respect, simplicity and security are the two primary goals. Cumbersome network settings can possibly be dealt with in the computer world but certainly not in the mobile and consumer electronics world. The main driver for creating the Near Field Communication Interface and Protocol (NFCIP-1), was to make the users able to create a connection between two devices without any special knowledge about the "network", yet any NFC-compliant device could be connected securely. The concept is strikingly simple: in order to make two devices communicate, bring them together or make them touch. As the two devices identify each other, they exchange their configuration data via NFC and then the devices can set up and continue communication either with NFC or via other (longer range and faster) communication channels (such as Bluetooth or WiFi).

In Fall 2002, Sony and Philips reached agreement on the development of Near Field Communication (NFC) technology. In order to promote NFC worldwide, the two companies submitted the draft specifications to ECMA International, the organization responsible for standardizing information and communication systems. After developing open technical specifications, NFCIP-1 was approved under EMCA-340, and subsequently submitted by EMCA International to ISO/IEC. It has received approval under ISO/IEC IS 18092. The NFCIP-2 standard allows interoperation with RFID, Proximity Card (ISO/IEC 14443: 2001, Identification cards – Contactless integrated circuit(s) cards – Proximity cards) and Vicinity Card (ISO/IEC 15693: 2001, Identification cards – Contactless integrated circuit(s) cards – Vicinity cards) devices and readers by defining a mechanism for selecting the three operation modes as part of establishing the connection.

Communication systems for video surveillance tools The combination of video surveillance and communication systems have been tested for metro applications in the PRISMATICA [14], STATUE [15], ESCORT [16] projects and a first generation system is already deployed on the RATP line 14 and Singapour [17] underground in specific tunnel environments. In the case of urban buses the RATP systems AIGLE et ALTAÏR were a first step based on low capacity professional radio. Projects like, TESS [13] SECURBUS in Belfort [18], LOREIV in Marseille [19] and EVAS can be also mentioned. In the TESS project a DVB-T link using the Worldspace geostationary satellite was successfully experimented to transmit passenger information in urban busses. In the EVAS project a specific WiMax link have ben experimented in Lille and innovative tools for audio event detection have been proposed to design a new bi-modal surveillance system adapted to an embedded context. Some bricks developed will be re-used in the BOSS project in the context of the railway environment.

Existing cellular systems allowing multimedia communication such as GSM, GPRS, EDGE and UMTS offer poor bandwidth efficiency in the downlink direction. Even if the problem of high communication costs for nominal traffic mode, it is impossible for these systems to cope with the flexibility and high traffic demand in crisis situation.

2.2 State-of-the-art on wireless mobile transmission links

In today's offer the high data rate and mobility access is not realistic particularly from the train to the ground due to the poor spectral efficiency of existing systems. In the French national project TESS [13] the inadequation of existing cellular systems have been demonstrated in the case of data transmission from a moving urban bus and a control centre.

Recently many new signal processing schemes have been proposed and are being studied to increase the wireless capacity link taking into account the mobility issues. The main topics of interest are, MIMO/MTMR links, adaptive links, cross layer optimisations, interference cancellation, ... Some of these techniques are proposed as options in the standards and need to be evaluated to guarantee they will lead to the expected capacity and robustness expectations.

Ongoing standards such as 802.16e, 3GPP+, 802.20 and 802.22 aim at providing both mobility and high throughputs. To do so the signal processing schemes that are generally foreseen are based on diversity techniques (MIMO), new coding and modulation schemes and adaptivity as presented in the previous section. These issues need thus to be qualified in order to evaluate their impact on the system performances. Convergence between WMAN and 3GPP+ is also foreseen that could lead to lower cost deployments.

For the application of these wireless links to the project objective, we can identify two major issues. The security issue will require mainly a large uplink (from the train to the ground) whereas the travellers need would rather be ADSL like service with a large downlink throughput and a smaller uplink. In this scope, two main directions will be followed: the throughput increase and the coverage increase. In both cases, multiple element antennas are accurate as the capacity increase may be used to work at lower SNR and/or increase the throughput. For a capacity increase to be achievable using point to point links, it is necessary to have sufficient propagation diversity for the MIMO channel to increase the capacity. Notice that the antennas could be distributed along the train. For a capacity increase in a multi-point to point link, the capacity increase is made by making multiple links with either the train or the access points (the links sharing the same bandwidth and transmitting simultaneously.

A harsh issue in the specific context is the short coherence time of the propagation channel. Indeed, due to the speeds of the trains and the specific propagation conditions, the propagation channels will vary drastically than the one experienced in the today standards developments that focus on pedestrian applications. Efficient capacity increasing schemes rely on the propagation channel knowledge requiring fast tracking/prediction and robust communications links.

3 Relevance to market needs and expected impact

The BOSS project will provide the communications systems needed to develop new telecommunications applications in the domain of public transport. The major impact will be on societal benefits to European end-users, both in terms of confidence in terms of security of the transport system and comfort feeling and transport efficiency especially during off-peak hours.

3.1 Technological innovation and strategic relevance

The objectives presented in Section 1 will be reached by the development of a dedicated architecture relying on the interconnection of the indoor world (or train) and the outdoor world via a common and unique IP gateway. As illustrated by Figure 1, the IP gateway will allow to interconnect a set of both wired and wireless accesses:

- Cameras and microphones dedicated to a bi-modal surveillance, aiming at ensuring a high security level for passengers and employees by alerting on abnormal events;
- Sensors dedicated to maintenance needs, aiming at providing alarms and machine functioning state information to any supervisor able to manage them;
- Mobile units with wireless access via indoor wireless network (e.g. WLAN), carried by on-board supervisors (e.g. controllers), aiming at ensuring a second level of safety/security by being able to react to alarms/alerts and also by being able to release such alarms/alerts

Wireless access via outdoor network (e.g. UMTS/WiMAX) between train and ground control centre where in-depth events detections or maintenance analysis can be carried out, as well as specific security/safety actions launched (e.g. calling the police to come to next train stop).

Mobility new approaches Due to its target use case, the BOSS project is considering not only one level of mobility, but two levels. The first one corresponding to mobility inside the train itself, which can be viewed as a traditional setting for the mobile user considering the train reference frame. The second mobility level, which takes into account the mobility of train itself in the terrestrial reference frame. As such, the BOSS Project is targeting a dual mobility mode with a guaranteed QoS level.

Example of scenario for the BOSS project demonstration Based on the BOSS IP gateway architecture presented in Figure 1, and based on the partners experience in the domain, a first example of scenario is described hereafter, in order to illustrate the type of application that the BOSS architecture could offer. This scenario corresponds to the transmission of an alert, for example due to a passenger's health problem, to the distributed control centre for immediate action.

Communication from/to train and distributed control centre (see Figure 2) A train (especially sub-urban trains) will cross several types of wireless network, from GSM-R/GPRS/UMTS/WiMAX and WLAN, and soon future systems such as 802.16e (mobile WiMAX) and 802.22 WRAN (Wireless Regional Area Network). Based on its IP mobility capability, the BOSS architecture will select the adequate outdoor wireless link for transmission of the data to the control centre. In practice, the IP gateway sees the outdoor wireless link as just another link in its network, and the control centre as another node in the global IP network. By one or several hops the data (alert, context, ... as well as other data if necessary) are then transmitted to the control centre for analysis or action.

Abnormal event detection (see Figure 3) A camera installed in the passenger car, and connected to the IP gateway by a wired link, films the scene that is then analysed by events detection tools for generating an automatic alert in case of abnormal event detection, or by means of a manual alert transmitted over a wireless link to the IP gateway by a mobile supervisor (e.g. controller). The health problem is here detected.

In the same way, a set of microphones is connected to the IP gateway and capture the sound environment inside the vehicle. Audio signals are then analysed to automatically detect some events. In overcrowded environments where occlusions appear, a single visual analysis is not always sufficient to reliably understand passengers activity. Sound can be a salient information to deal with ambiguities and to improve detection/identification rate.

Decision and feedback The alert having been given, the control centre will launch the adapted procedure. If available a local team will be able to take over immediately assembling the appropriate medical team and sending it to the next train station for immediate care of the passenger. In the case where the alert was an automatic one, the control centre could also decide to alert the controller

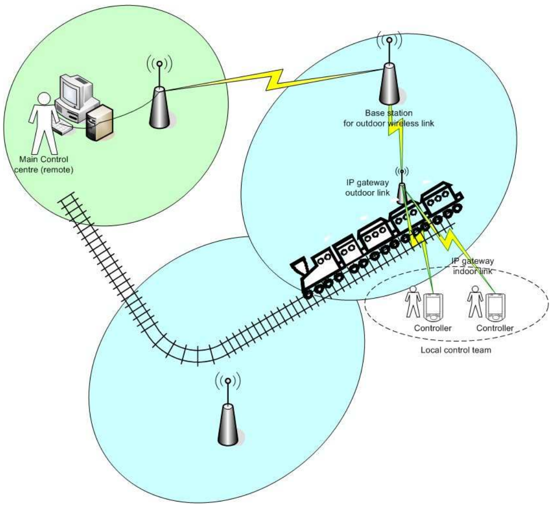

Fig. 2. Scenario example: communication from/to train and distributed control centre

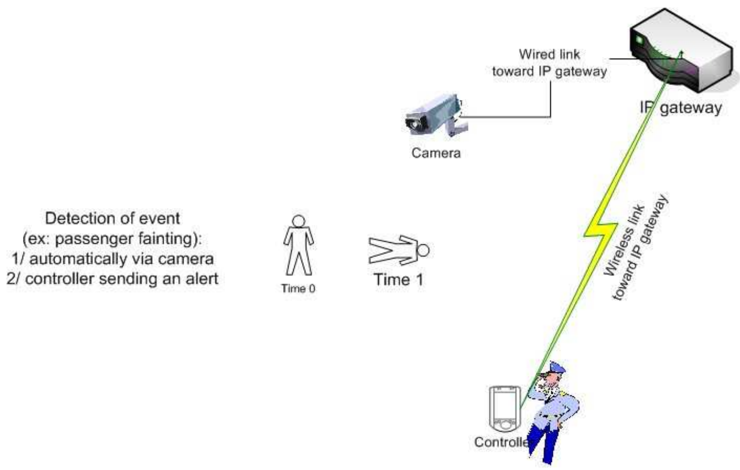

Fig. 3. Example: video surveillance and abnormal event detection (health problem)

by return channel to direct him/her to the sick passenger and help directing the medical team. This feedback capability will also be used by events detection systems to adapt their detection process and sensitivity according to relevance measures information from surveillance operators.

4 Conclusions

This article introduces the Celtic project BOSS. The BOSS project intends to develop a communication system relying on an IP gateway inside the train that will enable the communications both inside the train, for communications inside carriages and for mobile passengers and controllers, and outside the train, mobile in the terrestrial reference frame, with a link towards wireless base stations (e.g. WiMAX, DVB). The BOSS project will consequently work on a dual mobility level, and will work to guarantee a differentiated Quality of Service for the different targeted services. The project partners will also work on video surveillance applications adaptation, in particular via

- the robustification of the existing tools and development of behaviour analysis algorithms to ensure that the passenger security is handled in the best possible way,
- the addition of audio processing tools to increase the confidence of a generated alarm in situations where a single video analysis is not sufficient.

As an enhanced level of railway passenger security services is highly demanding in terms of bandwidth, this application thus represents a good case study to validate the BOSS concepts. Moreover, taking advantage of the bandwidth made available both downlink and uplink, wireless communications solutions such as video on demand, internet access, travel information services, ... which greatly interest travellers, will be integrated in the global BOSS framework via an adapted level of service management.

The BOSS project, with its IP gateway, is willing to offer the mobile train the possibility to inform a control centre both security, and trains exploitation related issues, and consequently to greatly increase the user protection as well as demonstrating the possibility to offer at the same time video on demand, onboard information and telecommunication services to the travellers. Validation will be performed through on-line tests on train in revenue service.

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