Overview

The European Commission has identified the ubiquitous access as one of the main elements in the evolution of the Internet, and it represents a Key Enabling Technology of the Information Society. Furthermore, the proliferation of mobile devices equipped with processing power is leading to the birth of a new era of ubiquitous communications, where a user will use several electronic platforms, thus accessing all information wherever and whenever he likes. Mobile terminals are becoming the gateway between the information sources (e.g. sensors, detectors, warning devices, actuators) and the Internet global mobile services (health, education, environment, transport, etc..). In particular, in wireless communications, vehicular networks stand not only as a key technology to provide connectivity and access to the Internet on the move but also to increase security on the roads, transport efficiency, and a proactive environmental monitoring. The potential of this technology has been recognized by establishing an ambitious research programs worldwide, such as the e-Safety initiative in Europe, the U.S. programs derived from Intelligent Vehicles, and the initiatives InternetITS and AHS in Japan. The research activity at the base of vehicular communications is focused on the architecture of self-organizing networks, also known as (mobile) ad hoc networks (MANET networks, mesh networks, opportunistic networks, and sensor networks), where the devices can auto-configure themselves by establishing a network of communications at the best convenience, even in the absence of fixed infrastructures. These technologies allow the extension of the Internet utilization, by using devices equipped with wireless communication interfaces (phones, PDAs, music players, cameras, cars, etc..) and realizing the transportation of the information from one device to the next one, up to the final destination. Many are the application scenarios that can benefit from this innovative communication approach, such as the provision of ubiquitous access to the Internet, the monitoring of the pollution, the tracking of goods in transportation, and so on. Moreover, these networks are the most promising for developing communication systems that can replace or support traditional systems in case of emergencies caused by natural disasters, failures, and attacks. It is also important to note that ad hoc networks may have an important role not only in after an emergency but also as a mean of prevention. Indeed, in ad hoc networks, sensor networks and RFIDs are valuable tools for monitoring pollution, transport infrastructures, and danger alerts. The Smartbus proposal is just located within this macro area of broadly shared interest. The project aims at studying and developing a prototypal implementation of an innovative platform to be installed on the already existing urban and extra-urban transportation media to transform them from passive objects (devoted to the passengers transportation only) to objects active in the social life, able to operate security and surveillance in the city, entertainment, multimedia data collection and delivery towards a control center, and environmental monitoring. The smart public transportation vehicles are particularly interesting because they represent a possible focus for the convergence of vehicular communications, opportunistic networks and, therefore, ubiquity in the communications of urban and suburban areas; we will concentrate on the buses. Any urban and extra-urban (or long-distance) bus, other than simply transporting passengers, becomes a medium with enormous potential, if we think of it in an innovative manner, equipped with services devoted to the passengers, the environment, and the security in the cities. In an urban environment, each bus of a certain bus line, repeats its journey at constant time intervals; thus, it can operate video-surveillance along its route, it can collect and deliver data, it can offer information and entertainment to tourists, and it can act as a mobile probe for environmental monitoring. If we extend this concept to all the urban buses, it is clear that they can constitute an enormous data source, without any structural change in the current bus structure. In addition to all this, extra-urban buses (coaches) may offer a mobile internet access, whose importance is not so evident in the short urban paths. Thus, by adding an innovative platform, any simple bus becomes an attractive and smart mean of transportation and communication, whose position is made known by satellite positioning systems. This provides a global coverage of the urban area and a geo-referred data retrieving. The frequency of the transits also ensures the repeatability and redundancy of the measurements, thereby improving the estimation. The benefits of this approach are:

° It dramatically reduces the cost of acquiring data relevant to the pollution in the monitored areas. The acquired data are available (almost) in real-time and geo-tagged area; they can be submitted via the web to all interested users.
° The acquisition of large geo-tagged time series allows implementing assessments and accurate models, otherwise not feasible. The platform can be used as an instrument for studying long-term behavioral patterns of users, the preferred routes, points of aggregation, and so on, in order to reschedule and optimize the stops and the timings of the bus lines.
°The communication platform is open to many different applications: touristic info, payment cards, bus on calling, entertainment, being it expandable both vertically by integrating new sensors and detection systems, and horizontally, in order to provide functions and additional services to passengers and transport companies.

The Smartbus proposal aims at the study and the experimental implementation of an ubiquitous innovative platform to be installed on existing public transportation vehicles. This will allow transforming buses into an advanced service provider, such as acting as an access point for mobile Internet, as probes for the detection of certain parameters of environmental pollution, collecting pictures along the routes, and collecting data from sensors installed at fixed points along the roads. If public transportation becomes appealing to the users, being them passengers or public administrations, in the cities the following advantages will derive:
° less car traffic;
° reduced pollution (as a consequence of previous point);
° improved security (on board, and inside cities);
° less stress (due to car driving).

Hence, the ubiquitous communication platform provides:
° a concrete action to drastically reduce the cost for providing services to citizens and public administrations, by using the bus as a mobile point of convergence;
° a reference system, to provide a tool for collecting environmental data in a capillary and efficient way, on any territory;
° a communication infrastructure and ubiquitous interconnection on the urban territory.

Low power consumption is important; in this sense, there are many aspects that can be investigated in order to achieve a low-power system. First, the possibility of a self-powered supply by means of a small photovoltaic panel equipped with an accumulator is an excellent way to get the system rid of the constraint of a battery or AC power, with the benefit of the costs related to power supply. For these reasons, the we can try to incorporate a low-cost photovoltaic system by ensuring the necessary energy supply to the system; we can test it in a real situation, to evaluate the applicability of this solution in the design of the prototype. Furthermore, the usage of "clean" energy would be an added value for a system whose purpose is the assessment of the air quality. Part of the work will be focused on researching on sensors to build a small size low-power system. Currently, the electronics of a monitoring unit includes, in addition to the control components of the sensors (working temperature and gain of the operational amplifier, both remotely manageable), a microprocessor that handles command inputs, data storage, and communications with external devices. To encourage the development of a low-power low-cost system, the goal of the project is to investigate means of radio communication with high efficiency, that can ensure a low power consumption and reliable wireless communications to the data collection center. In order to complete this task, there are two possible technical solutions: the sensors can be mounted directly on the vehicle, or they can be placed on the road, communicating with the vehicle during its passage. In both cases, the wireless communication is a good solution because it facilitates the development of a solution that can be implemented in different communication contexts (infrastructure to vehicle, vehicle to vehicle, etc. ...), but it requires a deep study of the aspects of mobile communications. A critical aspect is the current communication standard for sensor networks, IEEE 802.15.4. In fact, it has not

been particularly designed for vehicular communications, but it puts the basis for a highly efficient communication system, especially in the context of transportation of a small amount of information, such as the instantaneous measurements of pollution. From the point of view of the vehicular communication network, the project includes the study of all the issues related to communications between the infrastructure and the vehicle (I2V), communications among sensors organized in local wireless networks, and appropriate access methods that ensure consistency and integrity of data transmitted between devices in motion. In particular, we consider the factors that affect the performance of communication protocols with low power consumption (such as IEEE 802.15.4), by means of a measurement campaign aimed at assessing the loss of data packets and the signal strength received on a vehicular IEEE 802.15.4 channel. In fact, the performance will be evaluated in various channel conditions, assuming various situations of mobility of the sensors. The main results obtained with the measurement campaign will be mainly used in two research activities, concerning the study and implementation of a scheduler for managing the access priority, and the optimization of IEEE 802.15.4 MAC for vehicle transmissions. The first goal will be achieved by establishing different priority levels for the data transmission and by analysing suitable techniques that minimize the transmission errors. The second goal will be achieved by studying an algorithm that exploits the access methods provided in the IEEE 802.15.4 standard, in order to make the communication efficient, in terms of data delivery timing in vehicular environments, and robust against the channel multiple access. In fact, the standard provides an additional set of parameters that, if suitably optimized, can contribute to make the proposed algorithm efficient. Finally, the study of vehicular communication networks must also include the analysis of transmission systems not yet standardized but that have as a goal the definition of a new vehicular communication protocol (such as IEEE 802.11p). In this context, the performance evaluation of the new protocol, by means of an accurate measurement campaign, is needed in order to investigate the levels of the received signal strength and the integrity of the information exchanged in different scenarios of acquisition. The results obtained will be an input for the study and the definition of algorithms for a reliable point-to-multipoint communication. In fact, the problem of congestion control that occurs in emergency situations will be analyzed; congestion arises when multiple devices attempt to simultaneously send warning messages or high-priority information. The development of the network is based on the intelligent exploitation of the available resources in the urban environment, such as buses, taxis, and vehicles that, in general, are pervasively and constantly in the urban area, periodically retracing the same routes and thus providing capillary mobile coverage to citizens. Public vehicles represent the access points for local vehicular networks in the urban environment and can become a mobile unit for data gathering and environmental pollution measurements. In order to allow the vehicle to effectively communicate with the Internet and thus to transport the sensitive data received by the VANET and WSN present within its own coverage range, a backbone to the vehicle has to be provided, allowing permanent Internet access. Moreover, this backbone will be integrated with other existing networks and communication systems on the territory in a self-oragnizing and opportunistic way, on the basis of the available resources. This urban communication infrastructure, independent of the existing cellular networks, also enables secure connectivity even in emergency situations due to disasters, cyber attacks, or blackouts. In this context, satellite networks represent the most attractive solution, as they satisfy the basic requirements of ubiquity, security, bidirectional access and they ensure a dedicated service. The European Space Agency (ESA), in collaboration with European (and Italian) companies, is going to experiment the early prototypes that implement DVB-SH, a standard protocol for satellite communications to handheld devices and smart phones. CNR-ISTI will be asked to participate in the field trials by providing the know-how and the scientific basis for studying solutions that improve the reliability and the development of this technological platform. The testing includes the study of vehicular communications satellite in S-band (2-4 GHz) through the W2A satellite, whose launch is expected in the first quarter of 2009, which will be entirely devoted to broadcast communications to handheld and vehicular terminals. For this activity, we cab take advantage of the collaboration with MBI, the company that designed the DVB-SH platform for the J-Ortigia project

(http://www.awe-communications.com/Projects/J-ORTIGIA). Moreover, we can design a satellite / terrestrial transmission channel from the mobile vehicle to the Internet; this channel is the return path of the satellite broadcast channel DVB-SH. We can focus the attention on all the specific protocols for broadband communication via satellite within the DVB family. Finally, we can identify and evaluate the most suitable protection techniques to make the communication as reliable as possible for transporting multimedia content to / from the vehicle. The aim is to ensure the forwarding to the Internet of reliable data, collected by sensors, and video streaming taken from surveillance systems. This protection will ensure the integrity of the information received from vehicles, taking into account the possible obstacles that might obstruct the line of sight between the transmitter and the satellite. Some aspects of the project, such as retrieving data from fixed sensors by means of mobile vehicles, can be adopted in the context of railways, such as trains, subways, for monitoring the state of the crossed structures (bridges, tunnels, etc.).

State of the art

Although there is a vast literature on equipment for the development of safer cars, there is not so much research on the vehicles for public transportation in the sense that we mean. In 2001, the IEEE Intelligent Systems journal published a document MyBus on the results of one of the intelligent transport systems, funded by Department of Transport of the United States. MyBus, on the base of the forecasts of the departures and the arrivals at bus stops, provided travelers real time estimations of departure / arrival time of buses through the web browser of cell phones. The system is operating in the area of Seattle (USA), and its use is limited to an information service on public transport. The University of Malaysia has proposed and successfully tested on 20 vehicles, between buses and cars, a system of intelligent management of the fleet of buses that integrates the power of Global Positioning System (GPS) and the Global System for Mobile communications (GSM) in order to provide real-time positioning. In contrast with systems that depend exclusively by GPS, the proposed system provides an higher positioning accuracy and it is able to monitor the vehicle in those areas where GPS signal is weak or unavailable. Today these systems for forecasting the arrival of public transport vehicles are more or less a technologically advanced reality. Under the Sixth Framework Program, the funded project MORYNE focuses on facilitating the enhancement and efficiency of public transport through the use of wireless sensor networks. The project ended in March 2008, with a live demonstration in Berlin. MORYNE looked primarily at two aspects: improving safety in buses and improving the urban traffic control. The safety has been improved through knowledge, at any time, of the position of the bus, of the state of traffic and of the surrounding area, through images and videos. In addition, MORYNE offers an easier management of traffic and control of lines by providing information and communication tools to the buses (traffic congestion, fog and ice, etc..). In 2007, Cisco launched a pilot project, called the Connected Bus, as part of the Connected Urban Development. The Connected Bus is designed to encourage customers in San Francisco to use buses by improving the quality of their journey. The project aims at promoting the use of buses with a positive impact on the environment, through information systems that make the transport of passengers and the management of the service more reliable, efficient and safe. The strategy for achieving these objectives involves the integration of 12 different processing units and antennas installed on each bus, and then making the data provided by each vehicle available to two different audiences: i) the entire block of data for the control center of operations of the municipality of San Francisco, ii) a subset of the data publicly accessible via touch-screen on bus, or provided via voice. A bus prototype has been shown in San Francisco during the Connected Urban Development Global Conference in February, 2008.

The above described achievements are gradually becoming a reality in European cities, albeit slowly; however, they are subsets of the sophisticated architecture that we plan to develop. Our fleet of buses are a technology platform open and expandable to all services that users would like to receive; none of the previously mentioned systems includes an on-board Internet service, and no

detection units fitted onto vehicles in motion for monitoring of environmental pollution exist, not even as prototypes. By adopting metal-oxide semiconductor gas sensors, it is possible to create small and low-cost systems, with the possibility of a remote control of the sensor's main parameters. The research on the materials and sensing mechanisms of these sensors, based on chemoresistive films, is leading to an increasing reliability on detecting the primary atmospheric pollutants (CO, NOx, O3, benzene,...), with the future intent of substituting the conventional systems. On-field measurements performed side-by-side to conventional instrumentation demonstrated that CO concentration can be monitored with a 1% uncertainty, and similar results for the other pollutants are expected in the mean-short period

Specific research topics

- Vehicular Communications in Wireless Sensor Networks (WSN)
Assess the factors that impact on the performance of vehicular communications in sensor networks, through a comprehensive measurement campaign, in order to evaluate the statistics on the data loss and the signal strength received on the IEEE 802.15.4 channel, in vehicular environment under varying channel conditions, assuming various situations of the mobility of the sensor.

- Optimization of IEEE 802.15.4 MAC layer for vehicular transmissions
Design an algorithm that exploits the access methods provided in the IEEE 802.15.4 standard, in order to make the communication both efficient, in terms of data delivery in vehicular environment, and robust against channel multiple accesses; tuning and optimization of the MAC parameters for maximum efficiency.

- Performance evaluation of IEEE802.11p protocol
Measurement campaign to assess the performance of the IEEE 802.11p (WAVE) protocol for investigating the strength of the received signal levels and the integrity of the information exchanged, in different scenarios; definition of procedure and software for carrying out the measurements and obtaining statistics relative to the data loss and signal strength levels.

- Reliable point-to-multipoint communication algorithms
Analysis of congestion control during emergencies, when several devices try to simultaneously send a warning message or information with maximum priority when alarms are forwarded by the vehicles or sensors that are in the same range of communication; study of algorithms for broadcasting and reliable multicast, in order to mitigate the effects of traffic congestion.

- DVB-SH protocol testing
Test of vehicular satellite communications in S-band (2-4 GHz) through the W2A satellite, expected to be launched in the first quarter of 2009, which will be entirely devoted to broadcast communications to vehicular and hand-held terminals.

- Access method to satellite vehicular channel
Design a transmission channel (satellite / terrestrial) for mobile vehicles, that is the reverse path of the satellite broadcast channel, defined in WP2 (ie DVB-SH/S2m), covering the technological aspects of handover between the land infrastructure and the satellite one.

- QoS on satellite systems with mobile users
Identify and evaluate the most suitable protection techniques to make the communication as reliable as possible for the transport of multimedia content to / from the vehicle, to ensure the forwarding to Internet of both reliable data collected by sensors and multimedia contents taken from video surveillance systems.