Paper

# Exploring agent-based wireless business models and decision support applications in an airport environment

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**Abstract—This paper describes an intelligent communication and decision support system for providing wireless services in an airport environment. A novel agent-based business model is proposed and the value chain is analysed for wireless applications. This system is studied and developed within the scope of the IST ADAMANT project, where the Athens International Airport (AIA) is used as the trial environment. First of all, a set of advanced, realistic decision support application scenarios enhancing the airport facilities both for the passengers and for the airport staff is identified. Most of the applications can be summarised as location-based personalised services. They refer both to airport internal users and to passenger users. In order to provide these services, location-sensitive service level agreements (SLAs) and radio resource management (RRM) are introduced. The design of such a system is envisaged based on a generic, multi-agent architecture, which is also presented in this paper.**

***Keywords—wireless application, multi-agent system, wireless business model, wireless SLA, radio resource management.***

## 1. Introduction

The advance in wireless communication market enables users to experience enhanced delivery of personalized services through the integration of various radio technologies. However, the existing management platforms cannot ensure the scalability and reliability for the interworking of different networks. Therefore, the need for research activities in network management by developing and validating flexible architectures for the support of heterogeneous infrastructures is apparent.

This paper presents an intelligent decision and management system (IDMS) for providing wireless services in an airport environment. This system is studied and developed within the scope of the IST ADAMANT (airport decision and management network) project, where AIA is used as a trial environment. The envisaged system will be capable of handling crisis situations, as its benefits are clearer under such circumstances. The approach adopted is generic covering any mode of trans-port; although within this paper it is limited to an airport environment, as the "hot spots" that are naturally generated there provide some of the most difficult challenges. A system, as generic as this, has not been implemented before and it is technically challenging.

A set of advanced, realistic application scenarios enhancing the airport facilities both for the passengers and for the airport staff is identified, which make obvious the need for a scalable anticipatory environment able to provide roaming/location-based and personalized services based on service level agreements. These scenarios include the internal bus arrival time information estimation, flight information display on demand, mobile video/photo information for security and surveillance, automatic billing application for airport fuelling companies, and passenger support in the area of the main terminal building.

To meet the requirements imposed by the above scenario, an agent-based architecture is proposed. The multi-agent architecture forms a framework for implementing the interactions between the very different types of entities involved in the proposed scenarios, whether at the service level or at the network transport level. This type of architecture also has the advantage of scalability and robustness of operation in congestion and emergency situations.

The SLA management for location-sensitive applications and business models for wireless applications in an airport environment are analysed. A hybrid business model balances the benefits of all business roles, where appropriate value chains ensure the market place will be running smoothly.

## 2. System overview

This section presents briefly the operational environment for the functionality of the IDMS. More specifically, it describes the airport environment main structure, the airport user groups, and the existing set of services and wireless telecommunication infrastructure.

The airport environment consists of the core building which is the main terminal (MTB) and satellite building, the administration buildings and the related building of all the airport providers (such as handlers, police, fire brigade, the air-traffic control tower), as well as the outdoor environment which includes the access motorway, the new metro station and the parking spaces. Four different categories of potential users, within this operational environment, can be identified: passengers, meters and greeters, the airport staff and other airport service and content providers (i.e., security companies, airlines, duty-free and facility companies).

Different communications services are targeted at the different user categories listed above. For the provision of these services, a telecommunication infrastructure has been developed. GSM/GPRS, WLAN and TETRA [2] are the wireless technologies used. An IP backbone network is provided for Internet services and the PABX network for conventional telephony services. The airport holds the airport services and operations centre (ASOC), which combines all critical airport operations mechanisms and controls. The airport operational database (AODB) contains real-time information about the arriving and departing flights and other flight related information (gates, stands, etc.). This information is distributed within the airport community via the flight information display system (FIDS). All the airport data is processed through a central security system, which is called the universal flight information system (UFIS). This provides technical and logical functions for an effective and reliable data processing of operational flight information and holds the central UFIS database of the airport.

# 3. Application scenarios

In this section, the set of applications that the proposed system supports for enhancing the operational environment of the airport is described.

### *3.1. Internal bus arrival time information*

This application aims at developing a real-time component that estimates the waiting time of a passenger at the bus stop, prior to the arrival of the internal bus service of the airport. Towards this end, the data transfer functionality of either the airport TETRA system or the GPRS functionality of the GSM system is exploited. Real-time data regarding the location (from on-board GPS units) and the speed of the buses will be sent to the ASOC, where suitable software will estimate their arrival time at the bus stops, within the airport area. From the ASOC centre, this information will be distributed to every bus stop, where a LED display or a flat screen will be available, or even to individuals' handheld devices.

### *3.2. Flight information display system on demand*

This application will provide on-demand arrival and departure information on portable wireless terminals, based on the existing non-personalized UFIS flight information system of the airport. This service is to be considered as an extension of the existing non-personalized UFIS applications, as far as new interfaces and communication infrastructure are concerned. Target users are the airport staff, ground handlers, airlines, concessionaires and passenger service providers. This service will be fully personalised according to individual customer or group preferences. For example, ground handlers are more interested in the exact time of arrival and the location of the aircraft, whereas concessionaires are more likely to be interested in time delays or predictions of the number of passengers transiting in the next hour. The system interfaces with the network resource management ADAMANT subsystem, providing relevant information to aid the resource management subsystem in its provision of pro-active congestion management mechanisms (e.g., the dropping of less critical user groups). Security issues will also be taken into consideration.

### *3.3. Mobile video/photo information for security and surveillance*

This scenario concerns the development of a mobile photo/video camera system for the real-time transfer of photos or video to the ASOC for security and surveillance purposes and back to the security/emergency staff. Potential users of this system are the airport security personnel, airport police, fire brigade and ambulance services, etc. Transmitting real time photographs and/or video of an emergency situation or accident, by the ASOC intelligent decision and management system, will provide instantly the necessary elements for the immediate evaluation of the situation and the rapid activation of the necessary emergency-response teams. The remote monitoring of the crisis event through instant photos or video will result in more effective crisis evaluation and measures. The images and/or video will be directed to the system users by the ASOC, according to their profile, location, the overall situation and the user's preferences. This application will exploit commercial off-the-shelf equipment enhanced with additional security and authentication mechanisms and the ADAMANT network resource management features, in order to provide connectivity to the security personnel under all network congestion circumstances.

Networks GSM/GPRS and WLAN have the capability to transfer multimedia data in order to provide real-time visual information, according to the users' location and the overall situation. The user terminal comprises a PDA equipped with a GPRS and IEEE 802.11b WLAN PCMCIA cards and a GPS device in order to extract precise location information. The recently deployed multimedia messaging service in GSM/GPRS networks can be an enabling technology for such an application. In the longer term, video streaming may be possible in areas with WLAN coverage or over future 3G networks. This service complements existing networks of fixed cameras that provide surveillance information from certain airport areas.

### *3.4. Automatic billing application for airport fuelling companies*

The aim of this application is the development of a real time component that will automatically charge the amount of fuel loaded onto an aircraft from the respective fuelling company. The IMDS utilises the SDS functionality of the TETRA system. Moreover, it combines the information granted from airport's existing FIDS system with locally stored information from fuelling trucks and drivers.

### *3.5. Passenger support in the area of the main terminal building*

This is the core application of the project, aiming at providing passengers with *personalised* and *location-based* information related to the airport, as well as broadband Internet access during their stay in the main terminal building. Users of this service can access the content through their mobile terminals (PDAs or portable computers), or fixed PCs located inside the airport premises. Services depend on passenger preference profiles, as well as the status (e.g., departing, arriving, or delayed) of the user's flight.
The service will be controlled by a session manager platform able to:

- Provide the passenger with the necessary flight information and according to his/her profile and flight status, guide him/her through the departure procedure of checking in, clearing security, and reporting to the departure gate.
- Allow the airport to track the passenger.
- Provide personalised information with respect to other airport commercial facilities such as restaurants, shopping, etc., especially to passengers who get to the gate early, or to business travellers making use of the airport lounges. Flight delays can increase the demand enormously, as travellers can be encouraged to use these commercial facilities. To this end, the IMDS can exploit knowledge about the user preferences and the type of trip (e.g., regular business travellers or travel for leisure).
- Inform arriving passengers about means of transport (to and from the airport), accommodation, and local tourist information.

This application will help the airport authority to offer a value-added service and increase the passenger satisfaction, and on the other hand allow them to make more efficient use of the time spent at the airport premises and to increase the concessionaires' incomes. Finally in this system, it is possible to extend the coverage area to other "hotspots" like conference halls, hotels, restaurant and bars, etc.

## 4. The agent approach of system architecture

This section describes the main agent architecture for the IDMS in the airport area. IDMS deals with resource management strategies for GSM/GPRS, WLAN and TETRA and addresses SLA management issues in the context of providing advanced services to the airport users. The IDMS architecture is based on the "one-stop-shop" business concept, which identifies all the processes that should be in place, in order to include a service in the business service portfolio. In that respect, in such a scalable anticipatory environment, the following business entities can be identified: the users, the service providers, the network providers for GSM/GPRS, WLAN and TETRA infrastructures and the content providers.
The development of the IDMS is based on multi-agent systems (MAS) [3]. This section introduces the components that comprise the main agent architecture and provide the framework for the interaction between the entities identified previously. More specifically, the following generic agent components can be defined:

- user agents (UA),
- user resource agents (URA),
- location agent (LA),
- service broker agent (SBA),
- service provider agents (SPA),
- content provider agents (CPA),
- resource broker agent (RBA),
- network provider agents (NPA).

The rest of this section is dedicated to the analysis of these agents and the description of their role in the IDMS.
The UA manages all the information related to the user terminal and behaviour in the airport, such as user preferences, travel information, privacy issues, etc. Every user of the IDMS owns a UA, located inside the user terminal. In cases where a terminal cannot support the UA software, a proxy user agent located at the SBA can be used. The UA is activated any time the user registers to the IDMS. Its main role is to set and update the user profile. Any time the user wants to make use of a specific service, the UA communicates with the SBA and sends an application request. The UA also performs SLA monitoring functionality by monitoring some crucial SLA parameters, such as the received bit rate.
Another important functionality of the UA is to update the user's location at certain intervals, in order to provide location-based services. In that respect, the UA sends location update messages to a LA via the SBA, in order to inform it about the current position of the corresponding user. The LA holds a database, which keeps records of the current position of all the users registered to the IDMS. It can then maintain information about the geographical location of the user at any time.
The SBA plays a key role in the whole architecture, acting as a mediator agent by providing the interface between the UAs and the SP agent components. The SBA performs on behalf of the IDMS, subscription and identity checks for incoming users. Furthermore, the SBA maintains user profiles containing information such as the set of services and applications that the corresponding users are willing to subscribe to and the reference quality level at which a specific service should be provided.
The SBA undertakes the responsibility of prioritizing and delivering the incoming messages to the appropriate agents.

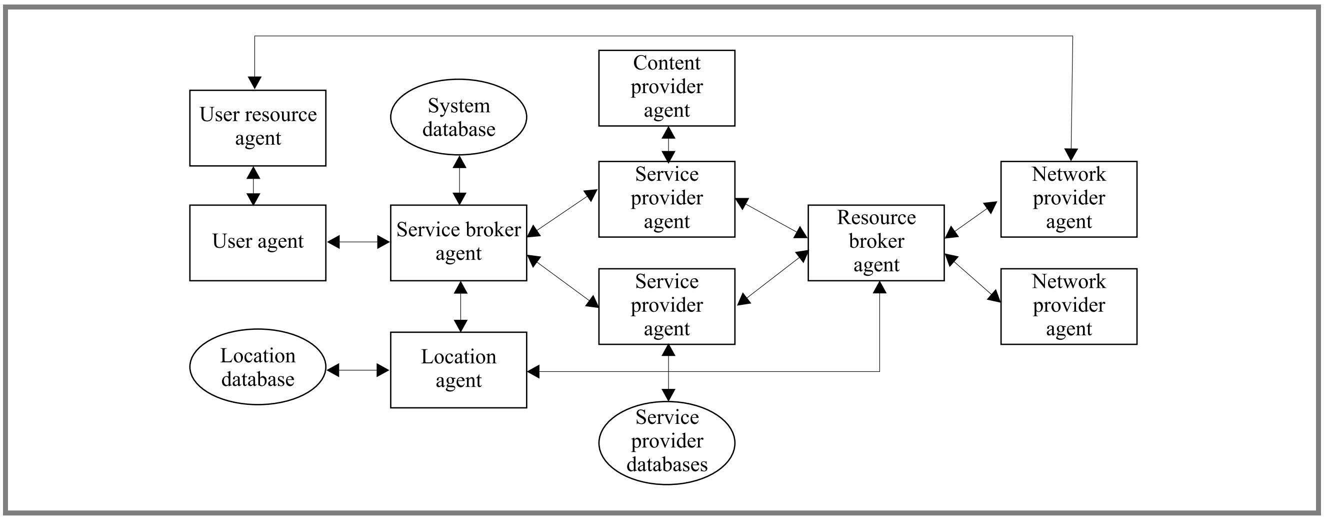


*Fig. 1.* System agent architecture.

The prioritization strategies can be based on many parameters, such as the type of the request, the SLA management policies and the preference settings of the UA. According to such information, the IDMS can decide about the priority given to multiple incoming service requests, with the aim of maximising the IDMS's profit.

The SBA can, also, act as a facilitator for SLA negotiation and notification functionality between the UAs and the SPAs. It is responsible for transferring and supporting SLA messages both from and to the SPAs. These messages may involve the SLA proposal of an SPA in response to the service request of a UA, the SLA response of the UA to the SPA and other SLA renegotiation messages.

The SPA maps to the existing entities of the airport environment for the provision of the available services. It is mainly responsible for the accomplishment of the role of the service provider to the end users. So, the role of the SPA is to respond to the requests from the SBA and offer the requested services to the UA, according to certain criteria and to retrieve pertinent information from local databases. In that respect, it communicates with the CPA, which provides service content information messages regarding the operation of the available services. The SPA can, also, perform SLA management functionality for the negotiation and monitoring of the SLAs with the UAs, through the SBA, and report any violations of the agreed SLA contracts.

The RBA is the gateway of the network domain with the other entities. Its main task is to find the best NPA to serve the incoming requests from an SPA. In that respect, the RBA should exploit the information gathered from the service domain and report to the most appropriate NPA about the facilitation of the specific service request. The incoming messages may involve the service type and other user related information. The RBA also interacts with the LA, in order to receive the user's location in the system. It can then decide the appropriate NPA with resource availability for location-based services.

The behaviour of the RBA is more important for the IDMS in cases of lack of resources, due to unexpected events, such as emergency cases and flight delays, which lead to local hot spots. In such cases, the challenge for the RBA is to find reliable solutions from the most appropriate NPA. In that respect, it should monitor the performance of the underlying networks, in order to identify the current congestion levels of the available networks and report any degradation in the system performance. So, at certain intervals, the RBA is informed by the NPA about (or alternatively infers itself) the current network status. Subsequently, the RBA can perform adequate functionality for finding the most appropriate NPA and ask it for resources. This functionality is crucial, especially in cases of high priority service requests, such as in emergency cases.

The network provider agent (NPA) is that agent in the system with primary responsibility for provisioning of the transport function for the services supported by the system. Hence, the role of a NPA is twofold:

1. **Negotiation**. NPAs "represent" the networks in the system's efforts to match the required network transport capabilities to the services requested by the user. A resource broker agent will contact one or more NPAs and by some mechanism, come to a contracted arrangement whereby one or more NPAs undertake to reserve and allocate network resources to the transport link needed for an agreed price.
2. **Resource management**. A given NPA organises its own internal resources, either in isolation or with the aid of other agents, to supply the agreed transport links with the contracted QoS arising from the first role.

In the context of the IDMS, there is one NPA for each of the access networks that are associated with the system, i.e., the WLAN system, the various GSM/GPRS operators, the TETRA network, etc. It should be noted that the NPA functionality may be distributed among a number of subagents within the network [1].

The user resource agent is an optional agent in the user terminal, with the role of collaborating with NPAs and/or other URAs, to control the user terminal's use of resources so as to optimise the operation of the user's transport link over the radio interface. The resources over which the URA may have influence include the air interface and usage of battery power.

Based on the description provided above, Fig. 1 summarises the system agent architecture for the accomplishment of the main objectives of the IDMS. As it can be seen, some of the agent components hold interactions with external databases, which then (partially) represent the necessary interface between the agent components of the IDMS and the external world.

# 5. Service level agreement management framework

As users move through an airport, they are roaming through the network, and the SLA management provided should be sensitive to the local conditions, adjusting SLA guarantees according to the roaming and location conditions as well as promptly notifying the user of these changing conditions. Location dependency of SLA is envisaged when users move between locations with different coverage characteristics or with different congestion situations (e.g., different cells of a GSM/GPRS/UMTS network) or when users move between locations served by different network technologies (e.g., UMTS/WLAN/TETRA).

In addition, in order to manage congestion and crisis scenarios, a service provider should be able to define policies to prioritise the allocation of resources to the most critical services and customers, to deliver the best possible service levels based on combination of SLA agreed with the customers and current conditions of the network.

The SLA management framework defined here is used to develop SLA templates and SLA contracts for service subscribers, in which the service level objectives may change as the user travels to or moves through the airport.

It includes components to: provide resource management with contracted SLA terms in order to allocate network resources (e.g., bandwidth) accordingly; monitor the service level experienced; notify compliance or non-compliance of the service level objectives; provide reporting functions for the detailed analysis of the service level offered by the network; communicate with service components to adjust the service behaviour based upon the management policies set by the provider.

Performing SLA management also implies coordination and exchanging information between providers in the value-chain and between providers and customers. Such coordination and information exchange is formalized in ADAMANT through the definition of business process models and the corresponding business interactions amongst providers, focusing on service management processes (e.g., service subscription, service assurance, service planning).

# 6. Business models and value chain

The business model of the ADAMANT system involves several different market players and can be characterized by multiple relations which, depending on the provided service, might differ.

In general, the following players are expected to be involved in the ADAMANT business model:

- **Customers/users**. In general, we can distinguish between the user of a service and the customer that subscribes to that service and negotiates a SLA with the service provider. In some cases they might coincide, e.g., in the case of passengers, in other cases they might differ, e.g., in the case in which a company subscribes to a service for a certain number of its employees. In ADAMANT, customers can be passengers, members of the Athens International Airport, ground handlers, etc.

- **Service providers**. A service provider (SP) is a company or organization that provides wireless communication services as a business. SPs may operate networks, or they may simply integrate the services of other providers in order to deliver a total service to their customers. Providing a wireless communication service to any one end customer may involve multiple SPs, where one provider may "sub-contract" to other providers to fulfil the customer's needs. According to the specific nature of the services provided we can distinguish among content providers, application service providers, service integrators/content brokers, Internet service providers, etc. In the ADAMANT context, depending on the specific application, content providers may be the AIA, e.g., providing flight information, or the airport concessionaires, e.g., airlines and travel agencies providing information about flight offers, or shops and duty frees providing information about special offers. The role of application service provider, service integrator and content broker is typically assumed by AIA (or more precisely, by some of its internal departments, e.g., the ASOC or IT&T departments), who acts as a "one-stop-shop" for services offered to the airport community. The role of Internet service providers is again covered by AIA, through its IT&T department. Other ISPs may be involved in the ADAMANT application scenarios, such as OTENet, and Panafonet.

- **Network providers**. These provide wireless communication services on an underlying network infrastructure, where, in this context,the services are basic telecommunication services, such as voice and data channels, IP capacity, etc. To be precise, network providers are actually a sort of service providers, i.e., providers of basic network connectivity services, so they can be considered as network service providers. We can distinguish the following sub-roles for network providers, according to the network technology used:

- mobile operators provide voice and data services on GSM/GPRS (and UMTS);
- WLAN operators operate WiFi (IEEE 802.11 [4]) wireless LAN networks in hot spots such as the airport main terminal; in the ADAMANT context the WLAN is operated according to the **neutral host model**: in this model the location owner, AIA, owns the infrastructure (access points, antennas, cabling, session management software, firewalls, routers) and offers it for exploitation to different providers, in this case to OTENet;
- specialized network operators provide voice and data services on specific network technologies.

As stated above, the classification of business roles presented above is useful to clearly separate functional roles within the business model, but it might be the case that, in a certain application scenario, the same business entity plays more than one role, or even different business units within the same organization, like in the case of AIA departments. It may also happen that the same business entity plays different roles in different application scenarios.

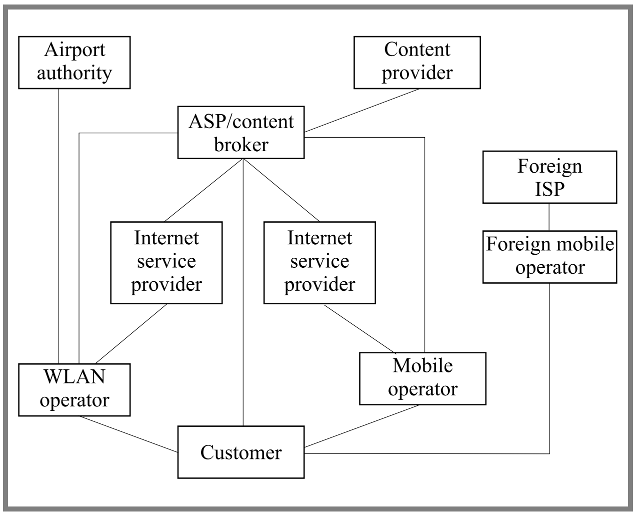


***Fig. 2.*** Business actors and their relationships in the ADAMANT context.

For the generic business roles, the customer (user) subscribes for a service with either a service provider or a network provider, according to the nature of the service requested and the specific business model used for providing that service. In fact, for the most generic case, it is possible that the customer, beyond having a direct relationship with the network provider, would also have a direct business relationship with the service provider. For example, not all services would be billed via the account the user holds with the network provider. Typically, a subscription for a value-added service could be performed with a service provider, while a network access/connectivity service could be subscribed to with a network provider.

The business relationships between roles in the ADAMANT context are depicted in Fig. 2. In the figure, specialized service provider and network provider roles have been added to reflect the actual service and networks typologies that are available in the designed application scenarios.

The customer may have direct relationships with both the service and network providers. Mobile and WLAN operators interact with Internet service providers (ISPs) for accessing the public Internet, and such ISPs in turn may interact with an ASP/content broker, either for providing Internet access to the ASP/broker, or to buy content from it. Mobile and WLAN operators may have relationships in the cases in which an operator may want to offer its customers services using the other operators' networks (e.g., a mobile operator offers download of video-clips to its customers through a WLAN when the customer is in the airport, which would be much faster). For the case of foreign visitors, foreign mobile operators are also represented, since these would have roaming relations with the local operators.

# 7. Conclusion

This paper has illustrated the on-going work of ADAMANT project, the application scenarios and the IDMS architecture. The paper also introduces the proposed SLA management framework for location-sensitive wireless applications and business models and value chains. Through the multi-agent architecture, the IDMS can provide management of the communication resources and ensure that the service provisioning of the airport users is in line with their SLAs. The new business model and value chain balance the requirements of all the business roles and ensure the smooth operation of the future wireless marketplace. Within this project, the IDMS system and new business models will be tested and validated through experiments, trials and demonstrations based on the defined application scenarios.

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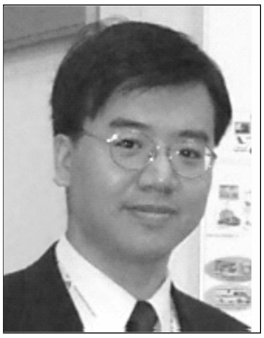

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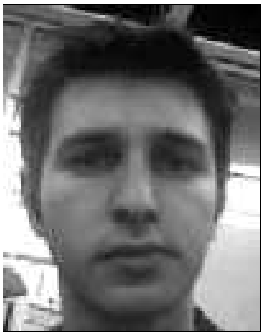

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