

# Administration situated and Agent-based Architecture Supporting Adaptable, Scenario-based and Context-mindful Provision of Mobile e-Learning Services

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**Abstract:** This paper depicts an OMG's MDA-based approach for the improvement of an administration situated and operator based middleware engineering supporting adaptable and versatile, situation based and setting mindful arrangement of portable e-Learning administrations inside InfoStation remote conditions. Considering the framework advancement as a procedure of cycles, the approach gives a broad capacity to analyze diverse improvement perspectives and expand the framework engineering well ordered. The initial two cycles, in particular the base middleware design and the situation based administration, are depicted in detail. A recreation domain utilized for testing the design is additionally introduced.

**Keywords:** m-Learning, adaptable software architecture, MDA-based approach, intelligent agents, mobile access, InfoStation environment.

## I. Introduction

A recognizable element of contemporary portable e-Learning (m-Learning) frameworks is the anyplace whenever in any case perspective [1] of conveyance of electronic substance, which is customized and redone to suit a specific versatile client [2], [3]. In the light of this pattern, we will probably build up a product engineering which can bolster m-Learning administrations conveyed inside a University grounds based InfoStation correspondence condition with circulated control. The InfoStation worldview is an augmentation of the remote Internet, where portable customers collaborate straightforwardly with Web specialist co-ops (i.e. InfoStations). The clients ask for administrations (by utilizing their cell phones) from the closest InfoStation by means of accessible Bluetooth (IEEE 802.15), WiFi (IEEE 802.11), or WiMAX (IEEE 802.16) associations. In our approach, every application using the InfoStation framework comprises of two segments: (I) an institutionalized middleware, which recognizes and finds the adjustments in the earth keeping in mind the end goal to get ready satisfactory conveyance of asked for administrations; and (ii) an arrangement of electronic administrations (eServices) – essentially e-Learning administrations – , which are adjusted and controlled by this middleware. In the first InfoStation design [4], the InfoStations work as middle people between the client cell phones and an InfoStation Center, on which an assortment of eServices are sent and executed. Anyway in our engineering, the InfoStations are go between as well as essentially benefit giving hubs. The usage of such engineering raises genuine difficulties. The principle one among these is identified with the help of appropriated control, which to have the capacity to recognize changes in nature (setting mindfulness) and as indicated by these progressions to offer the asked for administrations in more adaptable and proficient way (versatility). In the previous couple of years distinctive setting mindful frameworks for various reasons for existing were displayed in the writing. A design like our own particular engineering is introduced in [5]. This setting mindful design is made out of customers (moving hubs), setting server and middleware (settled hubs

associated through TCP/IP to the setting server). The middleware assumes critical part both in recognizing the customers utilizing the Bluetooth innovation and in finding an appropriate executable module as per the setting obtained from the setting server. Another design depicted in [6] utilizes a Context Engine for setting mindful conveyance of Web benefits by using a govern construct approach based with respect to first-arrange rationale for brought together handling of setting. In [7], a setting intermediary engineering in light of cosmology for setting portrayal is displayed. A setting mindful specialist co-op – a simple to a phone supplier – is portrayed in [8]. More typical setting mindful designs is put away and prepared centralized whereby the middleware is utilized essentially as a go between. In our design the setting is prepared essentially in the middleware parts conveyed on various InfoStations. The assurance of a specific setting is proficient inside the structure of predefined situations. To accomplish this, in specific cases it is important to recognize distinctive nearby circumstances occurring at various minutes and in various system hubs (InfoStations). In cases like these, synchronization between the middleware parts conveyed on various InfoStations is required. Another specifics of our engineering is that it is being created as an operator based one so as to:

- Model enough a genuine circulated framework;
- Allow for realization of distributed models for control;
- Show the pro-active behavior of the middleware (which is quite beneficial in many situations);
- Use more efficiently the information resources spread over different InfoStations.

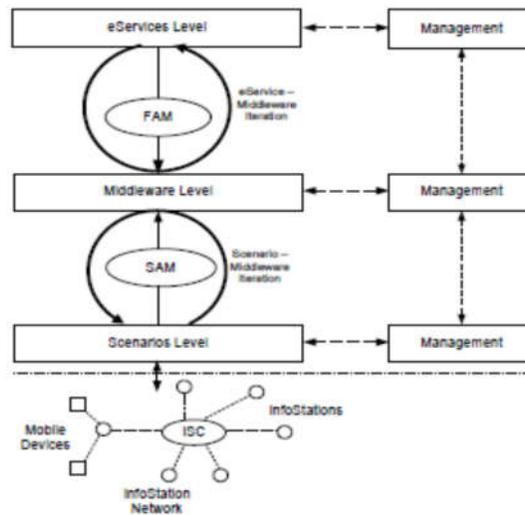
Moreover, the agent-based architecture is implemented as a set of autonomous agents, which could be easily extended with new agents that communicate by means of a standardized protocol, i.e. the FIPA's Agent Communication Language (ACL), [11]. This differs from the classic multi-tier architectures in which the relations between components at the same tier are much stronger. In our architecture we use tiers too; however, these are mostly logical groupings of autonomous components based on their functional characteristics. Another important problem is the context-aware provision of m-Learning services. To achieve context-awareness, the middleware must be able to identify/detect all changes occurring in the environment and adapt its behavior accordingly. Essential here is the concept of *context*. We use the Dey's definition [12], according to which "context is any information that can be used to characterize the situation at an entity". The entity could be a person, a place, or an object, which is considered relevant to the interaction between a user and an application, including the user and the application themselves. Context could be of different type, e.g. location, identity, activity, time. By utilizing the capabilities of the InfoStation infrastructure, in our architecture we want to ensure trouble-free, transparent and adequate execution of user requests for services by taking into account the changes occurring in regard to the user/device location, user mobile device, access network type (Bluetooth, WiFi, WiMAX), user identity, etc. This paper presents our approach for the development of a middleware architecture that is consistent with the fundamental principles of the e-Learning systems development suggested by the IMS Global Education Consortium, such as interoperability, service-orientation, component usage, layering, behaviors and data modeling, multiple binding, and adoption [13]. The middleware is being developed step-by-step, whereby the steps are considered as iterations. The first version of the middleware architecture, which was developed by following this approach, is presented here. We also discuss an extension of the architecture aimed at better control of service requests' execution in different scenarios.

## II. Approach

The improvement of setting mindful, adaptable and versatile designs is outstandingly troublesome errand, which is difficult to finish without an obviously characterized approach and without considering the major prerequisites without bounds framework. For the improvement of our m-Learning framework we utilized a product advancement approach [14] for encouraging the utilization of a specific design (InfoStation-based). The approach goes for the improvement of an administration arranged and specialist based design for effective use in on-line e-Learning frameworks utilizing an

InfoStation foundation for getting versatile access to eServices and instructive assets inside a University grounds [15], [16]. The approach depends on the thoughts recommended by the MDA determination of OMG [17]. In similarity with this approach, a design was based on three levels (Figure 1):

- eServices level – speaks to and models (utilizing an appropriate formalism) the usefulness of eServices gave by the framework;
- Middleware level – an operator based multi-layered level assuming an intercession part between the eServices level and the situations level. It offers shared usefulness: on one hand, it contains specialists required for the execution of various situations, and then again, it determines an arrangement of operators guaranteeing the best possible arrangement of eServices;
- Scenarios level – presents the highlights of the InfoStation engineering and the setting composes bolstered by it (as various situations), which are utilized for getting to the eServices.



**Figure 1.** The levels and iterations of the approach used

In addition, we examine the system development as a process of iterations. The term *iteration* – borrowed from the Unified Software Development Process [18] – means a workflow or cooperation between the developers at different levels so as to be able to use and share particular products and artefacts. We define two types of iterations in our approach: (i) between the scenarios level and the middleware level, and (ii) between the middleware level and the eServices level. In accordance with this approach we suggest a hybrid middleware architecture built upon intelligent agents and eServices. The eServices are convenient for the implementation of specific business functionality, but are static, however. The necessary flexibility, adaptability and collaboration features of the architecture, required for the context-aware middleware, are ensured by intelligent agents (which, however, are unsuitable for the implementation of functionality). The agents spot any change in the communications environment, carry out the adaptation necessary for correct processing of service requests, and activate the desired eServices. The following lower-level iterations are envisaged for realization in our architecture:

- *'Base Architecture'* – aimed to support the main scenarios characterizing the operational specifics of the InfoStation network [19], a base middleware architecture (presented in the next section) has been developed. More details on this can be found in [20], [21].
- *'Scenario-based Management'* – some important changes occurring in the user context during the execution of the users' service requests (e.g. the device mobility, when a user/device leaves the service area/range of one InfoStation and enters another) can be detected and identified by the system, only if the temporal aspect of this process is taken into consideration. Thus the goal of this iteration is to develop concepts and formal models, and to realize efficient scenario-based management of the offered eServices and active user sessions.
- *'Resource Deficit'* – in some cases

the user requests for particular services cannot be satisfied fully by the local InfoStation due to a resource deficit (e.g. when the information needed to satisfy the service request is unavailable on the local InfoStation). In these cases the service provision must be globalized in a manner involving other InfoStations. The software needed to support this type of InfoStation's interaction is developed as part of this iteration. • *'Adaptation'* – this iteration is concerned with problems related to strengthening the architecture, e.g. to support adaptability. In our opinion, personalized e-Learning process can be fully realized only by means of adaptive architectures, whereby the e-Learning content is clearly distinguished from the three models that influence the learning process – the user model, the domain model, and the pedagogical model. The user model presents all information related to the learner's individuality, which is essential for the realization of personalized learning process. The domain model presents the structure of the topic/subject for study/learning. In addition, in our architecture we want to support a goal-driven learning, whereby in case of a learner's request sent to the system, a concrete pedagogical goal is generated based on the pedagogical model used. The entire control of the user session afterwards obeys this pedagogical goal. These three models are supported explicitly in our architecture. They represent a strong foundation for seeking opportunities for adaptation to the environmental/context changes so as to ensure more efficient personalized learning (in this sense we aim at realization of a user/domain/pedagogical model-driven optimization).

### III. Base Middleware Architecture

The first version of the InfoStation's base middleware architecture, developed accordingly to this approach, is shown in Figure 2. The various agents employed perform different actions as summarized below. The *Scanner* agent searches for and finds mobile devices (within the range of the InfoStation) with enabled/activated wireless interface corresponding to the type of the InfoStation. In addition, this agent retrieves a list of services required by users (registered on their mobile devices upon installation of the client part of the application and started automatically by the InfoStation agents) and sends this to the *Connection Adviser* agent, which filters the list out. The filtration is carried out with respect to a given (usually heuristic) criterion. Information needed for the filtration is stored in a special database (DB). Finally, the Connection Adviser agent sends the filtered list to the *Connection Initiator* agent, which initiates the communication required for obtaining the service(s) requested by the user. This agent generates the so-called Connection Object, through which a connection with the mobile device is established (e.g. over WiFi, Bluetooth, etc.). In addition, for each active mobile device it generates a corresponding *Connection Agent*, to which it hands over the control of the established wireless connection with this device. The internal architecture of the *Connection Agent* contains three threads: an *Agent Thread* used for communication with the Query Manager agent, and a *Send Thread* and a *Receive Thread*, which look after the wireless communication with the mobile device. The *Query Manager* agent is one of the most sophisticated components of the InfoStation's architecture. It acts as a data distribution unit between the lower layer and upper layer of the InfoStation. On one hand, the Query Manager prepares and determines where information received from the mobile device is to be directed, e.g. to simple services, or to sophisticated services via interface agents. For this purpose, this agent transforms the messages coming from the Connection Agent into messages of the corresponding protocols, e.g. UDDI or SOAP for simple services. The direct activation of simple services (for example Web services) is possible without the mediation of Interface Agents. The latter are designed to maintain communication with more sophisticated services by using more complex, semantic-oriented protocols, e.g. OWL-S, [22]. In the opposite direction, the Query Manager agent transforms the service execution results into messages understandable by the *Personal Assistant Agent (PAA)* installed on the user mobile device. This is needed because the results must be returned to the relevant PAA, which has requested the provision of the service on behalf of its user.

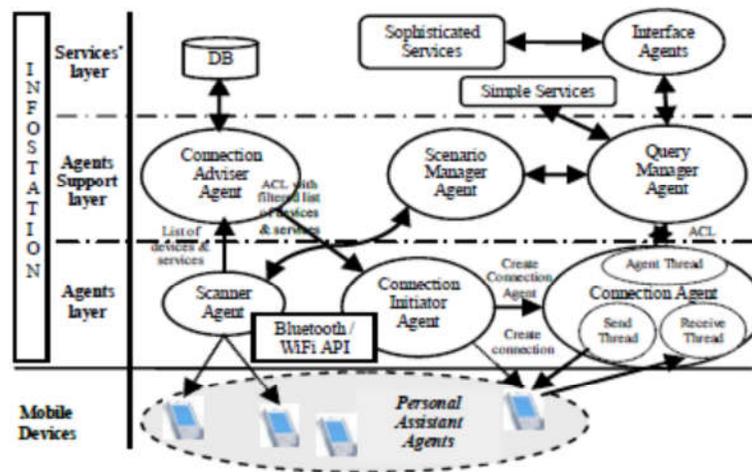


Figure 2. The InfoStation's base middleware architecture

#### IV. Scenario-based Management

Due to the supported user mobility and device mobility, the following four main communications scenarios are envisaged in the InfoStation architecture [23]:

- *'No change'* – illustrates the straightforward provision of a m-Learning service within the range of the same InfoStation and without change of the user device;
- *'Change of user mobile device'* – due to the inherent user mobility, it is entirely possible that during the m-Learning service provision, the user may shift to another mobile device (e.g. by switching to a device with greater capabilities, the user may experience a much richer service environment and utilize a wider range of resources);
- *'Change of InfoStation'* – within the InfoStation paradigm, the connection between the InfoStations themselves and the user mobile devices is by definition geographically intermittent. With a number of InfoStations positioned around a University campus, the users may pass through a number of InfoStation cells during the service session. This transition between InfoStation cells (i.e. device mobility) must be completely transparent to the user, ensuring the user has apparent un-interrupted access to the service;
- *'Change of InfoStation and user mobile device'* – most complicated scenario whereby the user may change the device simultaneously with the change of the InfoStation. The scenario management is performed by a dedicated Scenario Manager Agent (SMA) in our middleware architecture. Our aim is to extend and precise further the existent middleware architecture in order to be able to control the service requests' execution independently of the environmental (scenario) changes. Here we will consider the necessary extensions for the control of the device mobility and the corresponding two scenarios - *'No change'* and *'Change of InfoStation'*. First we will present our proposal for the control of the *'No change'* scenario. Then we will show that the *'Change of InfoStation'* scenario could be considered as a synchronization of two *'No change'* scenarios. For the control of the *'No change'* scenario, a *Request Register* and a *Mobile Device Register* are supported in our architecture. In addition, a relationship is supported between the records in these two registers such that each service request to correspond to a particular mobile device. The Request Register keeps information about all active requests in the system. The assumption is that the execution of a service request starts always according to the *'No change'* scenario. When a request is accomplished and the result returned to the user, the corresponding request registration is deleted from the registry. The Mobile Device Register keeps information about the mobile devices which are currently traced by the middleware within the InfoStation network. When an unregistered mobile device enters the radio range (service area) of an InfoStation, it is first registered. Correspondingly, when the device leaves the InfoStation and the

service request initiated by it is already accomplished, the information about it is deleted from the registry. However, if the service request is not accomplished yet, the registration of the corresponding device is not deleted but rather only deactivated. In situations like this, the request execution continues according to the 'No change' scenario, but the control expects possible changes in the scenario. If in the next moment the mobile device appears within the range of the same InfoStation, the 'No change' scenario remains unchanged. If the device enters the range of another InfoStation, then the control detects a scenario change and the service execution continues according to a new scenario (i.e. 'Change of InfoStation' scenario). As mentioned above, the 'Change of InfoStation' scenario could be presented as a combination of two 'No change' scenarios, which, however, are executed in different InfoStations. Moreover, the two scenarios must be synchronized to each other as to figure out whether they are two independent 'No change' scenarios or a 'Change of InfoStation' scenario is taking place (Figure 3).

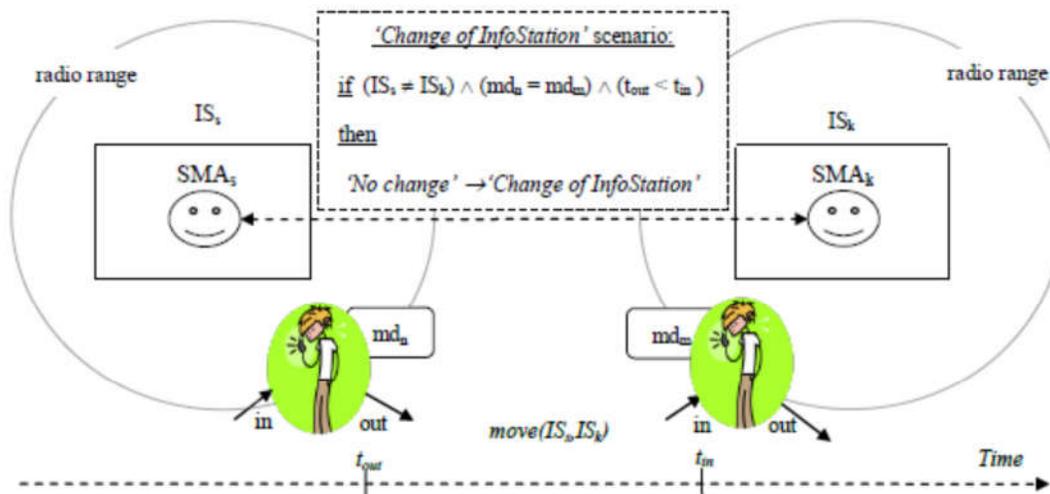


Figure 3. A scenario change during the service request's execution

For the realization of synchronization, we envisage two possible models: • *InfoStation-Center based Synchronization* – synchronization is done through the InfoStation Center. In this case, the SMA of one InfoStation (SMAs) sends to the InfoStation Center a Request Register's record of the activated request for mobile device mdn. When mdn enters within the range of another InfoStation ISk, SMAk sends the device ID to the InfoStation Center, which returns information specifying if the request is still active and which SMA controls it. Then the two SMA agents agree about the scenario change; • *Mobile-Device based Synchronization* – in this model, information related to an active service request is kept by the PAA operating on the device. When entering the range of ISk, the PAA communicates with SMAk to come to an agreement about the scenario change.

## V. Simulation Environment

A simulation environment is being created for testing the presented middleware. By means of this environment the middleware's behavior can be analyzed in the framework of separate experiments. The simulation system is being developed as a wrapper of the tested middleware, in which the following activities are carried out: • Preparation and initialization of the experiment. • Activation of the experiment execution. • Visualization of the middleware's behavior during the experiment execution. • Automatic generation of protocols, which may be used for the assessment of the middleware's behavior. The simulation environment consists of two main modules: an *Experiment Organizer (EO)* and an *Experiment Runner (ER)*, Figure 4. EO is a specialized user interface used for

the preparation of experiments and presentation of results. Experiments are presented as a specification; the results are recorded and are available for subsequent analysis. Beside this, some results may be visualized. ER is an agent-based wrapper of the tested middleware, which controls the experiment execution/running in accordance with the given specification. The interim results obtained during a particular experiment are transmitted to EO, where the experiment execution can be visualized. A generator of protocols has been developed also in EO. The simulation environment can present all events occurring in the middleware in the form of a log file, e.g. the actual moments when agents/containers/behaviors are created or removed, communications messages exchanged between agents, changes in the state of agents/containers/behaviors, etc.

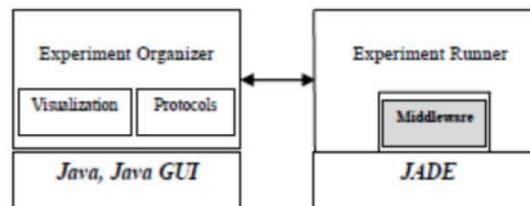
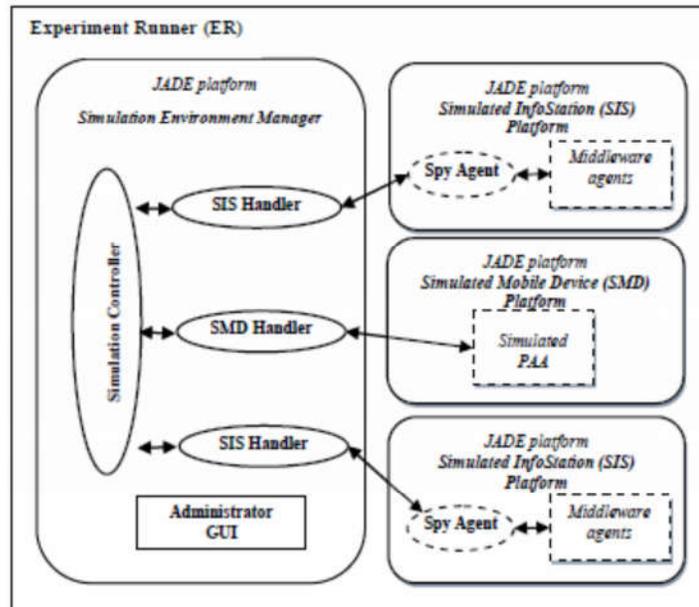


Figure 4. The logical structure of the simulation environment

- A. *Levels* The experiments, carried out with the help of this environment, allow research and analysis of the middleware's behavior at four levels as described in the following subsections.
- 1) *Scenario level* At this level we want to trace the global behavior of the middleware during the execution of the scenario designated in the experiment. Our particular interest is focused on the behavior of the resident agents and the process of generation of operational (temporary) agents, which depend on the changes occurring in the environment. These changes are specified in the description of the experiment and are simulated during its execution. As a result of the experiment, the following features of the middleware can be analyzed:
    - Tracking the movement of users and the corresponding reaction of the middleware.
    - Statistics about generated and removed operational agents.
    - Starting and completing a communication.
    - Data transfer between devices.
    - Review of agents on each hardware device.
  - 2) *Container level* At this level, for each simulated component (InfoStation Center, InfoStation, or mobile device) the simulation environment shows the active containers living in the middleware. The following information that characterizes a container could be extracted: the address, the identifier (identifying the container in the JADE platform [24]), the logical name, the port, the protocol used for communication, etc. The main container also contains two functional JADE agents: an Agent Management System (AMS) and a Directory Facilitator (DF). AMS is a mandatory component of the platform and is responsible for the overall management of its operation, such as the creation and deletion of agents, overseeing the migration of agents to/from the platform, etc. DF is an optional component providing yellow-pages services to other agents [24].
  - 3) *Agent level* At this level the simulation environment shows what agents live in the containers of each InfoStation. The following information characterizing an agent could be extracted: the name of the class whose instance is this particular agent; the local/global name for JADE; the state of the agent; the container in which it is located, etc. Beside this, different characteristics of agents can be visualized, such as the location of the agent (i.e. on a mobile device, InfoStation, or InfoStation Center), creation of an agent (the simulation environment catches the exact creation time and visualizes it along with the location, container, name, state), removal of an agent, etc. At the agent level a serious consideration is given to the detailed presentation of the states of agents. The agents can be in one of many states, such as *AGENT\_STATE\_ACTIVE* (the agent is in active state, i.e. at the

moment it carries out its functionality and is not awaiting any events from the JADE environment), *AGENT\_STATE\_DELETED* (the agent is removed, i.e. it has entered into this state just before its removal by the JADE environment and the release of resources held by it), *AGENT\_STATE\_IDLE* (the agent is in free state, i.e. it has fulfilled the assigned functionality and now it is waiting), *AGENT\_STATE\_INITIATED* (the agent has been just generated), *AGENT\_STATE\_SUSPENDED* (the agent is going into inactive “sleep” state), *AGENT\_STATE\_TRANSIT* (in this state the agent can be moved to another JADE container or another JADE platform), *AGENT\_STATE\_WAITING* (the agent is going into awaiting state), *AGENT\_STATE\_COPY* (the agent is going into state, which allows it to be copied), *AGENT\_STATE\_GONE* (the agent has already moved to another platform or container). This level collects also information that allows analysis of interactions between agents. The simulation environment may intercept messages exchanged between different agents. The information, which may be visualized for each message, includes: the sender, the recipient, and the contents of the message encoded in ACL. 4) *Behavior level* The purpose of this level is to provide opportunities for analysis and assessment of local behavior of individual agents. The agents maintain their own libraries of different “behaviors”, which could change depending on the environment. The simulation environment obtains the following information during the process of operation of the observed agents: the name of the behavior, the name of the class whose instance is this behavior, the type of behavior (simple or complex) and other behaviors contained in the current behavior (for complex behaviors only). At this level the simulation environment can visualize the following characteristics of each behavior: the behavior’s affiliation to an agent, the creation or addition of behavior, the removal of behavior, etc. Moreover the simulation environment can distinguish the following states of each behavior: *STATE\_READY* (this state shows that the behavior is ready for execution), *STATE\_BLOCKED* (the behavior execution has stopped for some reason, e.g. waiting for a message to be received, input/output operation, etc.), *STATE\_RUNNING* (the behavior is currently executed). B. *Implementation* This subsection presents in detail the architecture and implementation of the Experiment Runner (ER). ER has an agent-based architecture (Figure 5), implemented by means of JADE, which allows smooth integration of the middleware. ER consists of the following agents: • **Simulation Controller** – the desired configuration of the InfoStation (IS) network is simulated with the help of this agent. It is the central coordinator of each experiment that is currently running. This agent issues commands for the creation or removal of simulated InfoStations and mobile platforms, defines waiting intervals and the sequence of interaction between simulated mobile and IS platforms. This agent is also an interpreter to a specialized script language that describes the desired experiment. Currently we are studying the possibilities for using the Interval Temporal Logics [25] and its interpreter Tempura [26] for describing the experiments. • **SIS Handler** – this agent controls a separate **Simulated InfoStation (SIS) platform**. Depending on the purpose of the experiment and on the commands received from the Simulation Controller, it generates different commands addressed to the managed SIS and received by the corresponding **Spy agent**. The **SIS Handler** takes care of the creation and removal of the specific SIS, by setting the relevant parameters needed for the operation of the JADE platform and the desirable initialization of the **Spy agent**. • **Spy Agent** – the role of this agent is to execute the commands issued by the **Simulation Controller** agent on the **SIS platform**. In addition it provides feedback to the simulation environment on the events that have occurred in the **SIS platform**. • **SMD Handler** – this agent controls the simulated mobile device (SMD) in a similar way as the SIS Handler controls the SIS. He interprets the commands received from the **Simulation Controller** agent, processes them and submits corresponding commands to the simulated

**PAA.** The SMD Handler takes care of the creation and removal of the *Simulated Mobile Device* platform and its desired initialization. • **Simulated PAA** – this agent plays the role of a user’s personal agent; it simulates the user actions based on the commands it receives from the SMD Handler. It also provides feedback by reporting on the events occurring in the simulated mobile device platform and on the exchanged messages. Another task of its own is to connect to the various SIS and to issue requests for execution of services.



**Figure 5.** The architecture of the Experiment Runner (ER)

The ER’s agents are deployed on the following platforms: • The **Simulation Environment Manager** is a JADE platform, on which the *Simulation Controller* and the *Handler* agents live. It serves as a central console for the control of experiments. Work with the environment and visualization of the processes is carried out through a specialized graphical user interface (GUI) used by the administrator of experiments. By using this interface, the administrator of the simulation is able to issue commands to the controller, to start and stop experiments, to monitor the current status of the environment and the front conditions in the form of a log file. • The **Simulated InfoStation Platform** is a JADE platform on which the unmodified agents of the standard middleware are located. The only addition is the presence of the **Spy agent**, which provides a feedback to the controller. The SISs provide the same conditions for the operation of middleware as the real InfoStations, with only one difference that all of them are deployed on the same computer. • The **Simulated Mobile Device Platform** is a JADE platform, on which the simulated personal assistant is operating. This platform represents the mobile device of a single user.

- B. *Spy agents* The AMS agent on each JADE platform offers the possibility to other agents to subscribe for events occurring in the environment. Based on this possibility, in each simulated InfoStation a **Spy agent** is created which to detect the changes in the various JADE platforms and to send relevant information to the corresponding platform handler of the simulation environment. The handler in turn may forward this information to the simulation manager for visualization and further processing. **Spy agents** can subscribe to the following events: *ADDED\_CONTAINER*, *REMOVED\_CONTAINER*, *BORN\_AGENT*, *DEAD\_AGENT*, *MOVED\_AGENT*, *CHANGED\_AGENT\_STATE*, *ADDED\_BEHAVIOR*,

*REMOVED\_BEHAVIOR*, *CHANGED\_BEHAVIOR\_STATE*, *SENT\_MESSAGE*, *RECEIVED\_MESSAGE*, *POSTED\_MESSAGE*, *CHANGED\_AGENT\_STATE*. In order to be able to receive information about these events, each **Spy agent** must engage in communication with the AMS agent using the ontologies provided by JADE (i.e. the JADE-Agent-Management-ontology, Introspection-ontology, and FIPA-Management-ontology). A **Spy agent** may be configured to provide snooping on a specific group of agents. Information collected by the **Spy agent** could be easily filtered out for subsequent visualization, e.g. to display only that part which is of interest.

## VI. CONCLUSION

This paper has presented an OMG's MDA-based approach for the development of a service-oriented and agent-based middleware architecture supporting flexible and adaptable, scenario-based, context-aware provision of m-Learning services within an InfoStation environment. To achieve context-awareness, the middleware is able to identify/detect the changes occurring in the environment and adapt its behavior accordingly. Considering the system development as a process of iterations, our approach provides an extensive ability to examine different development aspects and extend the system architecture step by step. The first two iterations, namely the base middleware architecture and the scenario-based management, have been described in more detail. A simulation environment used for testing the architecture has been also presented. The presented middleware architecture is implemented by means of the JADE framework [24]. Currently we are looking for a suitable way for formalization of the scenario presentation as to allow the Scenario Manager Agent (SMA) to successfully identify different scenarios executed (or changed) during the run-time. The development of a formal context-awareness model will be based on the Calculus of Context-Aware Ambients (CCA), [27].

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