Chapter 2

Analysis of Application Scenarios

Imagination is the beginning of creation.
You imagine what you desire;
you will what you imagine;
and at last you create what you will.
George Bernard Shaw

In this chapter, we introduce selected application scenarios for event notification services that will be used throughout this thesis to illustrate newly introduced concepts. We show that new applications have emerged that require the efficient integration of event information from different sources under various or changing application requirements. Examples for such *integrating* or *multi-purpose* applications are facility management for commercial buildings, traveller information systems, logistics control services for warehouses, and E-Learning systems.

The application areas are illustrated by scenarios for integrating event notification services. For each application, the observations are summarized as (1) the current situation of ENS, (2) the providers of event information, (3) the typical clients and their profiles, and (4) the event processing demands.

As a summary of these observations, the chapter concludes with the definition of six requirements for an adaptive integrating event notification service.

2.1 Remote Monitoring and Control

The group of remote monitoring and control applications is one of the important domains for adaptive event notification systems. Examples are monitoring of factories, powerplants, and facilities. The

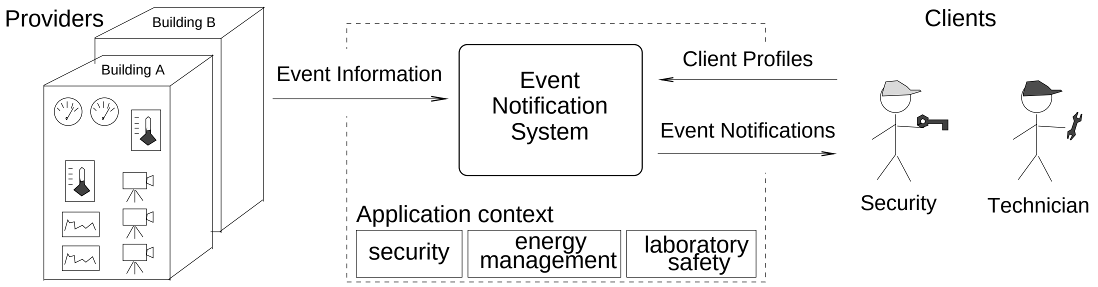

Figure 2.1: Event notification in a facility management system

domain has gained strengthened attention with the upcoming of new techniques in mobile communications [Sch00], such as Bluetooth [Blu03] and UMTS [Thi99]. Newly emerging applications involve mobile vacation home controlling, video-based surveillance systems, Internet-based facility management in commercial big buildings, and environmental monitoring services. Here we focus on a facility management scenario.

2.1.1 Scenario 1: Facility Management in Commercial Big Buildings

A *facility management service* is a distributed system for the remote monitoring and control of multiple heterogeneous commercial big buildings (CBB) across the Internet from a single control center. Application examples are facility management in buildings such as the Sony-Center or the Treptowers in Berlin. The component for event monitoring and notification is called surveillance system. The services are currently based on installation bus systems for CBB, such as European Installation Bus (EIB^{TM}) [EIB03], Local Operating Network (LON^{TM}) [LON03], and Luxmate^{TM} bus system [Lux03]. These bus-systems provide a communication network that can support about 12,000 clients (data sources and sinks) [EIB99]. Current systems provide only basic control functionality for facilities, different technologies are managed independently. A surveillance system for several buildings monitors lighting, heating, air conditioning, sun protection, and visitor movements. Various sensors are located within each of the monitored buildings (see Figure 2.1).

Some sensors send status information on a regular basis to the system. Other sensors send only critical events, i.e., if the status values cross a predefined threshold. A third group of sensors passively collects data and is to be observed (polled) by the system. Sensors may also have different reaction times and granularities. For example, Siemens offers at least six different sensor types for luminance measurements, which may additionally be programmed for different behavior [Sie03]. For the tracking of visitor movements in a building or at the premises, several techniques may be employed: Clients wear personalized badges, such as the infra-red-based Active Badge [HH94] and the ultrasound-based Active Bat [WJH97]. The badges transmit a signal every few seconds; the signal is received by widely deployed sensors throughout the building or marked transmitter stations (e.g., as done at the Berlin Marathon 2002). An event source module can retrieve all badge sightings for all clients. The event notification system can be used, for instance, to set alarm whenever someone enters a restricted area of the building.

Several different applications may use the data from the event notification service: access management, security, maintenance, energy management, laboratory safety, and budget management (for an extensive requirements analysis, see [SBF98]). Each of these applications may use the data in different ways. In multi-purpose buildings, the applications may change frequently. For example, depending on the actual usage of multi-purpose buildings and rooms, the surveillance system of a building covers certain profiles and events: For festive arrangements, the guests' security has to be ensured while for cultural exhibitions, strict environmental conditions have to be maintained for the presented pieces of art. The following examples demonstrate client profiles in a facility management system:

Example 2.1 (Profiles in Facility Management System)

1. *Notify a technician if in a certain room the temperature rises above* $35°C$ *within a time interval of 1 week length after a failure in the air conditioning system.*
2. *Notify a technician if the air conditioning system fails for the third time.*
3. *Notify security personnel if a window is broken (during the night) and after this a presence detector sends a signal.*
4. *Notify service personnel if a sensor did not send data for more than half an hour.*

These examples describe profiles with human-oriented time requirements, but other examples with stronger demands towards the event processing time[1] *are conceivable, e.g., for safety in a chemical laboratory.*

The building-specific security service may observe objects at night, whereas for the operator protection services (for employee security) low-activity periods at nights alternate with periods of high event frequency during the days. Thus, the workload of the event notification system changes. In addition, the notification of the technician depends on the usage of that room: whether it is used as a chemical laboratory or for a conference. In the former case, a much faster reaction is required and all critical occurrences have to be logged. In the latter case, the air conditioning only has to be adjusted.

Depending on the sensor type and the application, the technician has to be notified, for example, about *every* occurrence of that event or just the *first* one. Similarly, for each of the contributing events (see Profile 1: high temperature events and system failure events), different evaluation methods may have to be applied. As pointed out by Brügge et al. [BPR00], applications for cooperative buildings have to offer scalability in *quality* (i.e., for event composition) as well as in *quantity* (i.e., performance).

2.1.2 Observations

From the facility management scenario, we make the following observations and define typical characteristics for an event notification service.

1. Current Situation: Current remote monitoring and control applications are isolated systems that do not cooperate; personalization is rare (see also [OJM$^+$98b]). A market study of computer aided facility management systems [For02] identified 60 independent proprietary systems. Only few independent systems exist that may interact with components from different manufacturers.

[1] *Because an event notification service is not* responding *to a* request*, we call the time between event occurrence and notification of the client not 'response time' but 'event processing time'.*

Examples are OWL [BPR99], a system for home and office applications, and its successor FCB, a Framework for Cooperative Buildings [BPR00].

2. Event Providers: The event sources are passive or active sensors that measure different environmental conditions. The sensors provide event data with different semantics, e.g., sensor status, threshold crossing, amount of change. The ENS has to support sensors with observation frequencies on the order of one per minute, each provider supports hundreds of sensors. Apart from scheduled sensor readings, additional events in a CBB may have an overall peak frequency of 200 events per second [Lic03].

3. ENS Clients and Profiles: Profiles describe primitive events, such as alarm signals from environmental sensors (see Profile 1 in Example 2.1). They also define more complex interests in composite events (see profiles 2 and 3). In addition, profiles may describe events that did not occur for a certain time, such as the Totmann-principle[2] for security sensors (Profile 4). Several event compositions are conceivable. The number of clients highly depends on the application field, it can range from 100 (mobile service units) to 10,000 or more for environmental surveillance system and facility control. The number of different profiles also varies: In surveillance systems, profiles have high overlap, resulting in about 1,000 distinct profiles. In automatic facility control clients define unique profiles. Profiles are relatively stable.

4. Event Processing: Various applications may have to be supported within the ENS. The events need to be processed efficiently, time is crucial in surveillance systems. Detection and composition of events have to follow a certain temporal accuracy (e.g., time granularity in seconds for building management and earthquake forecast). The systems do not have to support real-time notifications, but real-time–aware event analysis. For automatic monitoring services in CBB, the service's event processing time must not exceed 0.1 seconds. Typically, surveillance or facility management systems may have several $10,000$ profiles, future systems are planned with up to 10^6 profiles [Lic03]. Large scale ENS have to connect up to $10,000$ sensors, resulting in an event frequency of 1000 events per second for each controlled building.

2.2 Logistics Control & Traffic Support

The field of logistics and traffic support is a newly emerging application area that rapidly extends the capabilities of radio-broadcasted traffic information news. Now, information from different services, such as public transport, highway information, and weather news have to be integrated. Example applications are traveller support systems that inform clients about changing travelling conditions. Similar information is needed in logistics applications that support companies delivering goods. For these reasons, we believe that integrating event notification systems will play a major role in this application domain. We describe scenarios for both logistics support and traveller information systems.

[2] Originally, Totmann circuits monitored the activities of engine drivers. Currently, they are widely used in mobile phones and hand-held devices.

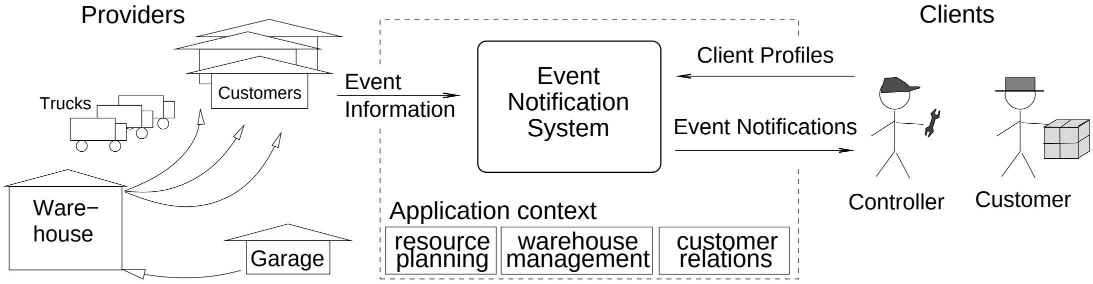

Figure 2.2: Event notification in a logistics support system

2.2.1 Scenario 2: Logistics Support System

A *logistics support systems* provides control for warehouse management and delivery companies. The movement of goods in the warehouse and their distribution is traced and partially automated.

An event notification system for logistics support may integrate information not only from on warehouses and delivery, but also on traffic and customers. Several applications may use the event data provided by the ENS: resource planning for the assignment of employees and vehicles on deliveries, warehouse management, and customer relations (see Figure 2.2). Clients of the system are employees in the warehouse, delivery-truck drivers, customer contact personal, and analysts. For example, clients that await deliveries from a warehouse are interested in the current status of a shipment. Currently, delivery companies post these status information in the Internet. An integrating ENS could actively inform the customers about events in which they are interested, for example, if a package remains longer than one day at a certain airport or if the delivery has been scheduled.

Possible events in the system include the start and arrival of each truck, the deliveries, accidents of the trucks, traffic information, and delivery cancellations. The following examples demonstrate client profiles in a logistics support system:

Example 2.2 (Profiles in Logistics Support System)

1. *Notify the controller if a traffic jam has occurred and one of the trucks is in that area.*
2. *Notify the analyst if a customer has cancelled orders three times.*
3. *Notify a customer if the truck may arrive within the next thirty minutes.*
4. *Notify the controller if goods have not been picked up two hours after the start of the shift.*

The profiles describe events concerning the location of certain goods and trucks, the traffic situation for a planned delivery, cancelled orders, and truck accidents. The events are provided by different event sources, e.g., sensors or the customer system. For the tracking of vehicles, the techniques for location tracking described in Scenario 1 (see Section 2.1) may be used.

Additionally, the service collects the information from several delivery services. The ENS has to integrate event information from sources that underlie different conditions, e.g., in accessibility and accuracy of event information. The providers of event data may change, e.g., a new delivery service or additional trucks are used. The systems workload changes over time: Deliveries are carried out during the day, while the truck fleet is maintained at night. Depending on client choice, notifications are send via email, or Short Message Service (SMS), or directly to the client's hand-held device.

2.2.2 Scenario 3: Traffic/Traveller Information System

A *traveller information system* supports travellers in planning a journey, in booking and paying, and receiving the travel tickets. For example, the Stadtinfo Köln [HS99] is a traveller information system that informs on traffic situations in Cologne. We expect a traveller information system to support not only drivers, but also travellers using public transport. Upcoming traveller information systems also advise travellers about how their chosen travel option is performing before they start the journey. On a journey, a *traffic information system* supplies traffic-related information for travellers. An example is the Canadian Traffic and Road Information System [Ont01], which informs interested clients about unscheduled and scheduled traffic events. Unscheduled traffic events are unplanned events such as collisions, breakdowns, emergency roadwork, vehicle fire, spill, and road conditions. Scheduled traffic events are events that are known in advance, for example, maintenance and construction.

An integrating systems supports travellers in the preparation of journeys as well as travellers on the journey: It informs the clients about events on their planned route, e.g, a traffic jam, the delay of a bus, a missed train connection, or a bad weather situation for the selected route. The service may announce cultural events en route, i.e., the profiles could be dynamically dependent on the client's location. Based on this data, alternative routes may be suggested. The following example demonstrates client profiles in traveller information systems:

Example 2.3 (Profiles in Traveller Information System)

1. *Notify the traveller about a traffic jam ahead.*
2. *Notify the traveller if their current train is late so that planned bus connections will be missed.*
3. *Notify the traveller about a concert starting at the destination after train arrival.*
4. *Notify the traveller about good weather conditions and the scenic view of an alternative route.*

An integrating event notification system for traveller information does not only coordinate information about various transport/transit facilities from more than one region, but also integrates data from various sub-systems, e.g., traffic information, public transport news, weather information, and tourist event calendars. The filtered event data changes over time, e.g., because the client is moving to a new area with new event data sources.

Clients are travellers planning a route and travellers on a journey. In both cases, client profiles define a planned route or journey, the travellers are interested in all events concerning their plans. The events to observe are primitive events (see Profile 1) as well as combinations of primitive events (see profiles 2 to 4). The current location of the traveller also influences the system. Notifications have to be delivered to the planning client, e.g., via email or Internet-interface. Notifications delivery to the client on a journey might influence the route, notification mode could be, for example, information delivery to a hand-held device. Timely information of the clients is crucial.

2.2.3 Observations

From the scenarios for Logistics Control and Traffic Support, we make the following observations and define typical characteristics for an event notification service.

1. Current Situation: The logistics and traffic support services today are lacking the employment of integrating event notification services that monitor and integrate events from different sources, such as weather news, traffic reports, and tourist information. Example services are web-based systems for travel planning that integrate information from different sources, e.g., TIScover [PRW98] and Informed Traveller [ICWH99]. Genesis [SF96] proposes an advanced traveller information system based on mobile databases.

2. Event Providers: The event sources are sensors collecting data, video cameras at traffic junctions, public transport information, or other event notification services (e.g., weather news[3] and cultural events). The servers may provide event data with different structures and semantics.

3. ENS Clients and Profiles: Profiles describe primitive events (e.g., Profile 1 in Example 2.2), events that do not occur for a certain time (e.g., Profile 4 in Example 2.3), and temporal combinations of events. The events need to be integrated from different sources, e.g., combining weather information and route planning with traffic information. Notifications have to be sent immediately, e.g., to the hand-held device of the client. The notification delay should not exceed several minutes, depending on the scenario. In logistics support systems, the defined profiles are relatively stable. The profiles in traveller information and traffic information systems are subject to change within hours or days.

4. Event Processing: Due to the high event frequency, an efficient event processing is required. Selected events or profiles may have a higher priority, for example, traffic jam events over scenic view announcements. Detection and composition of events has to follow a certain temporal accuracy in the order of seconds. The ENS has to connect up to several $10,000$ providers of information with a large number of clients, e.g., millions of travellers.

2.3 Web-based Education

Recently, systems for electronic support for individual learners have gained increasing importance due to increasing student groups and limited lecturing time in higher education. Additionally, the learning material is distributed over different libraries, the Internet, and university networks. Example applications are systems for mobile learners, Internet-based classrooms, and distributed learning repositories. Here, we describe a scenario for a personalized learning environment.

2.3.1 Scenario 4: Personalized Learning Environment

While a digital library offers its clients access to electronically available publications, a personalized learning environment offers additional course documents [FKRT03], literature, and Internet references. Examples are the Australian project WebWorkforce [Web03] and the European PADLR [PAD03].

The clients of such a system are students and teachers of courses (see Figure 2.3). In a learning repository, clients want to be notified about new course publications in which they are interested. The

[3] A service for weather information is, for example, Weather Information on Demand (WIND) developed at Fraunhofer Berlin [Fra02].

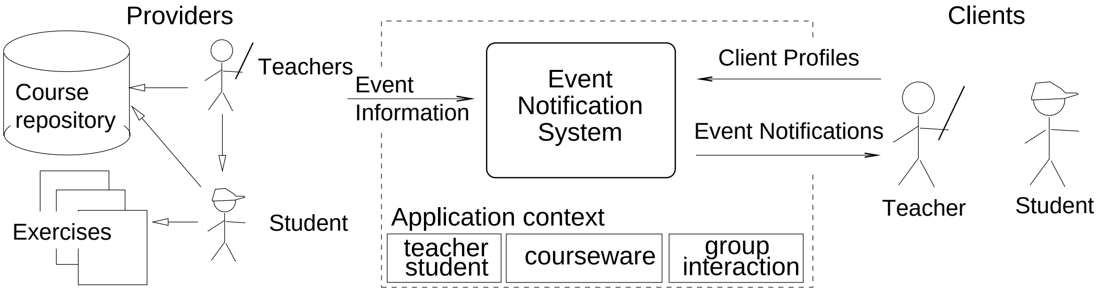

Figure 2.3: Event notification in a personalized learning environment

service could be used to guide the students through the courses. In this case, client profiles may describe the students background. Additionally, information about the courses that have been already accessed by a client may be considered. The service notifies not only about appropriate or new courses, but may also initiate and support learning groups in the network. The service additionally supports the preparation of practice documents by a group of students, e.g., by incorporating a distributed authoring facility [BAB97]. Examples for events are creating/changing/deleting a document, and adding/changing collaborators. Teachers may observe the progress of a student group via student-news-ticker. The following example demonstrates client profiles in a personalized learning environment:

Example 2.4 (Profiles in Personal Learning Environment)

1. *Notify the student about new courses on 'Event-based Systems'.*
2. *Notify the teacher if a student failed a course test for three times.*
3. *Notify the student group if all group collaborators have inserted their practice document.*
4. *Notify the student about a course after two prerequisite courses have been successfully taken.*

The service has not only to support a set of various event sources of growing number, but also various applications. Different applications refer to different courseware with corresponding teaching styles and requirements. Additionally, the participants may have different backgrounds that have to be taken into account. For example, advanced students receive more references to advanced courses and literature on the same topic than a beginner. Continuously, new resources are added to the system, student groups change and each students course-background changes.

2.3.2 Observations

From the scenario in the E-Learning domain, we make the following observations and define typical characteristics for an event notification service.

1. Current situation: Personalized learning environments are an upcoming topic, only isolated subsystems exist, e.g., the repositories OLR [DNWW01] and EDUCOSM [MKN+03]. Existing (sub)systems for collaborative authoring, e.g., WebDAV [WG99], or for collaborative work, e.g., BSCW [BAB97], are independent and not integrated into the learning environments.

2. Event Providers: Event sources are the course data repository and the document server. Additionally, the actions of teachers and students within the system cause events. These events have to be

observed by the system. Different providers may support different event semantics, e.g., owing to differing client programs.

3. ENS Clients and Profiles: Application-specific profiles and client profiles have to be distinguished. Application-specific profiles are defined by teachers for their courses, guiding the student through the course. Client profiles for teachers and students may change over time, e.g., depending on the clients progress in the courses. Profile numbers are in the range of 10^5 (e.g., students and teachers of several universities).

4. Event Processing: Efficient and scalable filtering is important, e.g., especially for the control of multimedia courses that should not undergo frequent interruptions. For the event composition, different time zones and transmission delays have to be taken into account. Various application forms have to be supported by the ENS, e.g., authoring and teacher-student interactions.

2.4 Requirements for Adaptive Integrating Event Notification Services

In this chapter, we described selected application domains for ENS and discussed novel and enhanced functionality that can be enabled through the employment of an adaptive integrating event notification systems. Abstracting from the single application scenarios presented in this chapter, we refine the observations made into detailed requirements for an adapting integrating ENS.

As seen in the scenarios, the new applications call for an ENS that flexibly supports both (1) various and changing applications and sources, as well as (2) efficient filter algorithms that keep high performance under changing system load. We call these two requirements *qualitative* and *quantitative adaptation*, respectively. For qualitative adaptation, depending on the available event providers and the application context, the profiles have to be evaluated differently: Notifications may be sent on every event or only once. Also, profiles may have different priorities. If the system does *not* flexibly adapt to the different event sources and applications, the clients are forced to redefine their profiles for every new event source. The challenge of quantitative adaptivity is evident: When the ENS covers additional event sources, more event data may be delivered – the system load rises and the event distributions change. The events and profiles also undergo application-specific variations: The overall distribution of events and profiles changes in the ENS. The ENS has to keep high performance under the changing system load.

In the following list, we identify six major requirements for qualitative and quantitative adaptation in detail. The order in the list of requirements is inspired by the data-flow sequence within event notification services as shown in Figure 1.2 on Page 3.

R1. Elaborated Event Model. It is not sufficient to report events as messages and filter these messages as documents without recognition of the event semantics. Without an event model, differing semantics of the reported events cannot be distinguished. Only an event model allows for correct detection of events that occurred at different sources and may be reported differently. Moreover, an elaborated event model supports a wide range of applications; it encourages the dynamic adaptation of event handling to various applications: Different event message types should be supported to enable the integration of differently structured sources. Additionally, different categories of events are needed: primitive events, temporal events, and composite events as well as the concept for events that did not happen. Unstructured event messages and simple subject based profiles (channels) are not sufficient.

R2. Active and Passive Observation. Information about events can be submitted to the ENS either directly by the provider or the event data have to be actively observed at the providers' sites: The ENS has to provide support for both active and passive event observation. Event information can be collected at various locations, for example, at distributed event sources (e.g., sensors) and at centralized application-driven locations (e.g., databases).

R3. Integration of Composite Events. This requirement is divided in two parts. First, event notification systems have to support *profiles for and the detection of primitive and composite events*. Primitive events are provided by the event sources; composite events are temporal combinations of these primitive events. Second, event notification services have to *integrate event data from different sources*, i.e., combine primitive events from various sources into composite events. We distinguish coordination and integration: Coordination describes the assembly of different components (different sources) under an umbrella interface with any interaction only achieved (indirectly) through the manual efforts of the system's clients. Integration implies an interaction between different sources, e.g., by observation of composite events formed by combination of events from different sources.

R4. Flexibility in Event Filtering. As shown in the scenarios, event notification services have to support various sources that employing differing event generation modes, e.g., sensor status readings at scheduled times, active sensors reporting status changes, new objects occurring or changing. The processing of client profiles has to be adaptable to new or changing event sources. Therefore, event notification services need a flexible way to homogeneously evaluate different kinds of events to the defined profiles.

R5. Temporal Awareness. For the composition of events as well as for time-dependent events, event notification services need to be aware of temporal restrictions, e.g., for the ordering of events. Real-time restrictions are not necessary, but real-time awareness.[4] Issues that have to be addressed are the lack of global time and the influence of delays in the accurate observation and ordering of events. Thus, temporal awareness is of special interest to the combination of events from different sources using different observation methods, e.g., the combination of the results of sensor readings.

R6. Performance and Scalability. Depending on the application domain, an event notification service has to support large numbers of clients and event sources. The number of clients influences the number of profiles to be handled by the service. The number of event sources, their event frequency and the event observation policy of the service determine the number and frequency of events a service has to process. The performance demands on the service, measured in processing time

[4]Note that one could envision scenarios for event notification systems that raise real-time requirements, e.g., flight control. This issue will not be addressed within this thesis.

between event and notification, are raised directly by the application and indirectly by frequency of events to process. Issues like network latency and observation delay need to be addressed.

Further, minor requirements that are not covered in this thesis are support for off-line or mobile clients, persistency for event messages and notifications, transaction context, context and location awareness and flexibility in notification schedule and mode. The requirement of scalability is typically addressed by distribution of the service. In this thesis, we do not focus on scalability but use the findings of the extensive research in that field [Car98, MFB02, PB02].

Given our observations, we identify the need for event notification services that collect and integrate event data from different sources considering various observation styles and event types. Additionally, the service has to adjust to varying application requirements, new event sources, and changing client profiles. We believe that this need is addressed best not by specialized solitary (or even proprietary) service implementations, but by an adaptive integrating event notification service. The requirements introduced here and the issues they raise are addressed in depth in the following chapters: The next chapter introduces our model for event notification services (addressing R1). In Chapter 4, we show the limits of existing ENS in their support of the identified requirements R1 to R6. Our design of an adaptive integrating ENS that fulfils these requirements is introduced in the central chapters of this thesis.