A Team Project in Information Technology Architectures

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Abstract

A team project for a graduate course in information technology (IT) architectures is described. The architecture development approach is based on the following rationale: An IT architecture should be designed in terms of an architecture framework which translates business drivers and initiatives into IT requirements for the acquisition and deployment of IT components. The case study for the team project concerned the modeling of enhancements to an existing E-business system. Project teams in the class followed an architecture design methodology to model the application, data and physical infrastructure perspectives, respectively, at various levels of abstraction using UML notation. The models were integrated into a comprehensive IT architecture, and was documented by means of the Enterprise Architecture Blueprint (EAB) Methodology. Various industry standards were adopted for managing the project work and for executing the technical tasks.

Keywords: Information technology, Software architecture, system architecting process, information systems development method, information systems education

1. INTRODUCTION

In most successful enterprises today business processes are carried out, or are supported by, information technology (IT) based systems. An IT system is interpreted as a combination of hardware and software (including middleware) that implements a solution to one or more business processes of the enterprise. The rapid changes and trends in IT are influencing how business is being done. In great measure the Internet has intrinsically altered the business environment, requiring that enterprises adopt IT architectures to capitalize on novel opportunities that are presented (Kara 2000). It has become imperative that an enterprise has a rigorously documented IT architecture that may be easily modified as dictated by new business opportunities or initiatives (Boar 1999). Such an IT architecture becomes a tool for maneuverability for the enterprise, i.e. providing the ability to optimize its strategic decision making by enhancing its IT resources to maximize it competitive advantage.

Due to the complexities of contemporary IT environments, and the multi-dimensional nature of IT systems, it is important to model the conceptual, logical, and physical views of the systems of an IT architecture (Rechtin 1997; IEEE1220 1998; IEEE1471 2000). These models must be understood in order to develop and implement an optimal system. It is a challenge to educators to provide students of IT and systems architecting with a learning experience that approximates a real world situation (Rechtin 1992; Buffington 2001).

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This paper describes teamwork on a case study and typical deliverables obtained when following an architecture development approach (Steenkamp 2002), as done in a 3 credit hour elective course in a master of science in computer information systems (software management) program. The choice of case study was influenced by the global interest in electronic commerce and customer relationship management, as is evidenced by the large number of business initiatives that continue to emerge (Lawrie 2001; Shim 2000).

The case study was derived from a real world Request for Proposal to enhance an existing Internet based E-business system for an automobile manufacturer. Some important issues needed consideration as we started work on the team project. For example, emerging technologies, such as wireless computing (Leeper 2000; Paulson 2000), component reuse (Griss 2001; Pernici 2000), computer-based architecting (Schaffer 1997; Hurwitz Group 2000), and application integration (Vinoski 1997), to name a few were investigated. In addition, it was necessary to determine the architecting principles that define the rules and guidelines for selection and deployment of IT components in support of the required enhancements. These principles enabled the selection of alternatives and consequently the components of a revised IT architecture. The project teams adopted an IT architecture process model and supporting architecting methodology that would enable them to model a logical architecture for the enhancements.

The paper documents the team experience in the following sections. Section 2 presents the case study and Section 3 summarizes the team approach that was followed. Section 4 presents selected views of the architecture followed by examples of the resulting documentation as explained in Section 5. The paper concludes with a discussion of the deliverables and lessons learnt in Section 6.

2. CASE STUDY

This section describes the case study in terms of the goals, a condensed system description, required enhancements, and specific enhancements for each of the viewpoints. It also addresses the principles relevant to the case study for each of the modeling viewpoints which the project teams considered.

Problem Statement of E-Business Case Study
The case study concerns enhancements for an E-business system for a global automobile manufacturer. An abstract model of the E-business system in relation to the enhancements is given in Figure 1.

Condensed System Description: The E-business system is accessible by a variety of users, namely consumers (Internet), retailers (Internet and company extranet), and the E-Business Consumer Assistance Center (CAC). The role of the CAC is to provide both consumers and retailers with process and technical support. Existing services include subsystems to select and locate a particular brand, vehicle model, trim level, color and optional equipment; to find and contact a retailer based on name, zip code, city/state or other criteria; to perform side-by-side comparison of competitor vehicles; to generate a "window sticker" with vehicle specifications, options and manufacturer's suggested retail price; and to enable the configuration or customization of a vehicle request/order.

Additionally, the system provides the ability to save vehicle configurations, shopping information and e-mail communications from retailers or the Consumer Assistance Center in a "My files" area. A number of financial tools, such as an affordability calculator, payment estimator and incentives are available, as well as support for a quick credit application that enables the consumer to determine how much financial assistance can be expected.

The E-business system is supported by an information hub integrating data from transactional source legacy databases supporting application systems for all the users, a persistent data store, a history warehouse and information-mart containing focused summaries and analyses.

Required Enhancements:

1. On-line order status – provide Internet customer with ability to check status of their new vehicle order. This component requires on-line, real-time access to the manufacturer's legacy Order Management System and Vehicle Information Database (VID). The Internet customer will be able to track the vehicle order from order receipt by the manufacturer through the milestones shown in Table 1.
2. Wireless Internet Access – provide accessibility of several core functions to a wireless Internet platform. Using a wireless Internet enabled device users will be able to perform the following functions:
   - Access product information by make, model and trim level (e.g. vehicle selector).
   - Find dealer.
   - Find vehicle (vehicle locator).
   - Contact retailer (message center/e-mail access).
3. Additional services – provide additional services via the Internet web site and wireless web access to attract and hold customer/consumer attention. These services will be purchased from a 3rd party provider and integrated into the web system. The desired new services include news, weather, stocks and traffic updates.
4. Enterprise Customer Management Integration – develop integration between the E-business system and the Customer Management Database to allow for a more personalized shopping and buying experience. The manufacturer's enterprise Customer Management System resides on an IBM

Tracking milestones							
Approved	Scheduled	Sequenced for Production	Broadcast to Production	Exit Production	Available to Ship	Shipped and In-Transit	Received by retailer

Table 1 Tracking a vehicle order

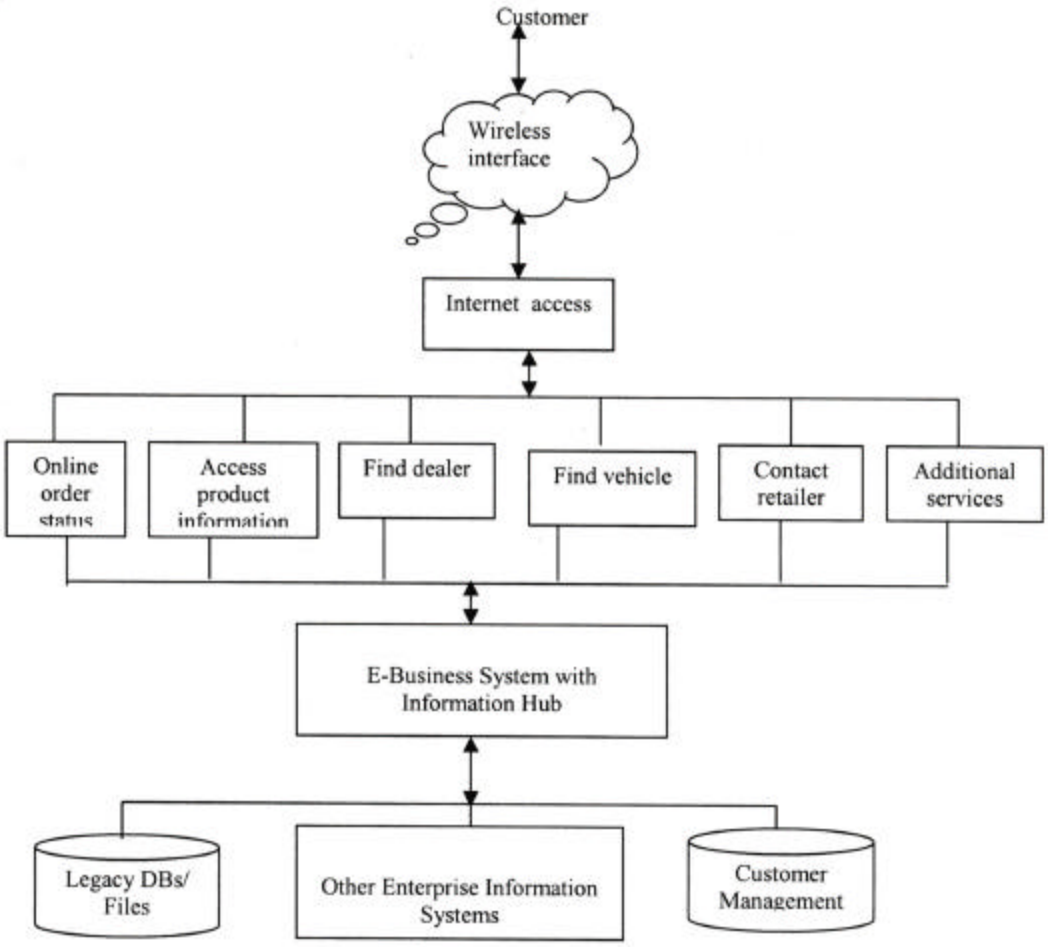

Figure 1 System context diagram of E-Business System

mainframe computer and utilizes IBM UDB as its database. The Information Hub, also called and Integration Hub/ Information-mart will enable access.

5. Infrastructure upgrade – if necessary infrastructure upgrades to support the new services above and to accommodate a 100% growth of utilization.

These enhancements were allocated to three teams, each one focusing on a specific architectural viewpoint, namely the application viewpoint, the data viewpoint and the physical infrastructure viewpoint respectively.

Team Project Topic 1 : The goal was to develop a proposal for an application architecture that will leverage the current E-business system components and accommodate newly developed and/or purchased components/services as described in the IT Architecture Assignment.

Specific requirements were as follows:

- Develop a multi-tier, web-based architecture that provides a highly scalable, secure and fault-tolerant environment for the management and distribution of the web applications, data and content. This should be presented in the form of a white paper

describing the details behind your proposed architecture.

- For each of the new services/components, show whether the user interfaces (UI) are HTML, JavaScript, XML/XSL, WAP/WML, Java applets, EJB, full-fledged applications, or a combination of the above.
- Show how each component internally interacts with the other components and back-end server entities, such as databases, web server, web application servers, content repositories, and third party hosted web services (e.g. middleware, connections, protocols).
- Propose a strategic plan for Enterprise System Management, which addresses web technology trends, and how the application architecture will evolve by leveraging such trends.

Team Project Topic 2: The goal was to develop a proposal for an enterprise data architecture model that will support integration of a variety of the manufacturer's legacy systems and 3rd party data sources to the E-business system web applications, and reflect the changes necessary for the newly added components/services.

Specific requirements were as follows:

- Propose corporate data standards to be used as guidelines for existing and new data. Ensure such data standards conform to automotive industry data standards.
- Perform system and application data mapping according to the following specifications:
  - Modify the existing data model and data dictionary to reflect the requirements of the new components/services.
  - Map new data entities and attributes, and 3rd party data to existing data tables (entities and attributes).
- Model data processes, i.e. processes that will govern how data is extracted, verified, cleansed, transformed/migrated, and moved into the E-business system database from the legacy data files. Propose in detail processes for:
  - Data extraction and collection from legacy systems and 3rd party vendors.
  - Data Mining, scrubbing and cleansing.
  - Data verification for validity against business rules.
  - Data migration and transformation. Indicate how data will be transformed/migrated into appropriate format(s) prior to getting loaded into the database.
  - Initial and ongoing data loading and required or suggested frequency of subsequent data loads/updates.

Team Project Topic 3: The goal was to develop a proposal for the physical IT infrastructure that will support the new integrated environment for the E-business system. Specific requirements were to develop:

- An IT infrastructure that supports the additional components and withstand a 100% increase in utilization.
- A proposal for a server farm infrastructure (firewall, Web server, application server, database server, etc.) for the development/pre-production, and production environments.
- A proposal for network and communication topologies. Address access lines (OC-3, DS-2, T-1, etc.), switches, routers, hubs, Ethernet (local & switched), gateways, distribution layers, redundancy considerations, etc. This should be developed for both the development/test and production environments. Ensure adequate redundant bandwidth to support global operation.
- A proposal for Service Level Agreement (SLA) with operational metrics (performance, availability, number of concurrent users, etc.) that insures the availability of the operational environment.
- A brief Disaster Recovery Plan.

Principles for the E-Business System Case Study

The project specifications were analyzed using an IT framework known as the Index Model (Boar 1999). The Index Model consists of a 16-cell matrix for defining the structure and constraints of the enterprise IT architecture. The rows of the matrix define IT assets of the enterprise in various categories or viewpoints. The columns of the matrix view these same assets in terms of inventories, principles, models and standards relevant to a category of asset (i.e. the rows). As is explained in Section 3, the architecting process called for an analysis of the business drivers and trends that led to the request for enhancements of the case study as presented in Section 2. According to the architecting methodology the IT requirements had to be determined and related to some overarching principles, design principles and buy principles.

The principles that were identified, based on the specifications of the case study, represent a business initiative of the automaker for an E-business system according to the methodology described by Boar (Boar 1999). These principles reflect the goals and business rules that were gleaned from the problem statement, and are summarized as follows:

- Provide consumer with an empowered electronic shopping experience, resulting in increased sales and market share for the manufacturer.
- Lead the automotive industry in E-commerce.
- Enable common, strategic, highly reusable electronic shopping components that can eventually be applied globally.
- Access to the information hub should be transparent to the users.
- The applications should be scaleable.
- Contingency measures should exist for disaster recovery.

These principles were analyzed and entered into the cells of the principles column of the Index Model for the

E-business system, as applicable, i.e. Infrastructure, Data, Application or Organization (refer Table 2). The principles impacted on the models that were developed for each of the viewpoints.

Viewpoint	Principle
Infrastructure	Interoperability, Portability, Adaptability, Reusability, Wireless Technologies
Data	Access to information hub, Access transparent to user
Application	Scalability, Security, Off-the-shelf purchase
Organization	Mission, Goals and Initiatives

Table 2 Principles guiding the development of IT architecture

3. APPROACH

The course was conducted by means of a set of lectures, presentations and team tutorials. The lectures explored trends and drivers in IT and their impact on the acquisition of such technologies. The techniques for modeling the viewpoints of the systems architecture were studied within the context of an architecting model and methodology.

Teamwork

Equipped with this background the E-business system case study was presented to the students (Steenkamp 2000, 2001). The class was grouped into three teams, each team charged with the assignment to model the enhancements for a particular system viewpoint, described in Section 2. The mode of teamwork and Internet-based collaboration is not discussed in this paper. The teams documented the resulting architectures and presented the deliverables to their peers and the sponsors of the project at the end of the term.

Architecture development process

The architecture process model that was adopted for the team project was a staged model with the following main stages: determine principles, IT analysis, build IT architecture, IT deployment, and IT architecture maintenance. The scope of the team project included stages 1 and 2 of this process model.

- Determine principles: to guide the decisions regarding the IT requirements to implement enhancement of the existing IT architectures as stated in the requirements for the case study. The principles governing the architectures are presented in Section 2.
- IT analysis: consists of two phases, namely
  - Analysis, where Functional Analysis, Data Analysis and Infrastructure Analysis are performed.
  - Logical viewpoint modeling, where Application Modeling, Data Modeling and Infrastructure Modeling are performed.

Architecture development methodology

An architecture development methodology was defined in terms of a series of steps to be performed in the stages of the architecture process model outlined above. The steps of the methodology are given in Table 3, and are described in more detail in (Steenkamp 2002). The techniques and notations used for each of the three viewpoints, namely the application viewpoint, the data viewpoint and the IT infrastructure viewpoint are summarized in Table 4 (Boar 1999; Booch 1999).

The application viewpoint describes the application architecture that meets the functional requirements of the E-business system. The data viewpoint describes the data used by the business from an enterprise perspective. The IT infrastructure viewpoint describes the IT assets of the enterprise, and includes hardware, systems software and network components in support of the applications architecture.

Project Deliverables

Each team was required to compile a project folder containing the models produced for the viewpoint in question. The project folder was arranged as follows:

1. Project planning document, derived from the IEEE 1058 Standard (all teams) (IEEE Std1058 1998).
2. The E-business system context diagram (all teams).
3. Architectural models and artifacts for the viewpoints as follows:
   - Application architecture and strategic plan for Enterprise Systems Management (team1).
   - Data model and guidelines for Corporate Data Standards (team 2).
   - IT infrastructure and Service Level Agreement and Disaster Recovery Plan (team 3).
4. Outline presentation slides (all teams).

4. VIEWS OF THE E-BUSINESS SYSTEM ARCHITECTURE

This section presents examples of the logical views of the architectures for the E-business system for each of the viewpoints: application, data and IT infrastructure. Due to the constraint on size for the paper we focus on the find_a_dealer function for a wireless client (refer Figure 1 and R1. in Table 5). Representation schemes for modeling the views were in accordance with the directives given in Section 3. The EAB notational rules that prescribe naming and numbering conventions helped in systemizing the large number of deliverables of the project. Computer-aided tools, such as the System Architect 2000/2001 of Popkin Software was used for developing the models (Popkin Software 2000).

Methodology Steps
1. Determine/ revise principles using an IT framework of choice
2. Analyze problem statement, and provide a complete definition of the problem domain
3. Determine the three viewpoints from the analysis
4. Gather information relevant to the issues of the problem in terms of each viewpoint
5. Define each viewpoint
6. Analyze the requirements in each viewpoint definition
7. Adopt a modeling notation for each viewpoint
8. Adopt a documentation method and notation for the project
9. Model the logical views starting with a context diagram using the CASE tool of choice
10. Document the logical models using EAB and the EAB templates
11. Develop Preliminary Team Proposals
13. Develop physical models
14. Document the physical models using EAB and the EAB templates

Table 3 Architecting methodology

Application viewpoint

The principles guiding the development of the IT architecture, as summarized in Table 2, were interpreted within the context of the required enhancements. These included the following:

- Applications implementing the EAB models of the enhancements should be acquired rather than built.
- All production applications must have a disaster recovery plan, and should be
- Scalable to be implemented globally.

The models of the application viewpoint were developed based on these principles and guidelines. Table 5 shows an example of a function table in terms of function and category for part of the specific required enhancements that were summarized in Section 2. Figure 2 is a high-level use case showing the external behavior when a wireless client interfaces with the dealership domain requesting information about a dealer. The behavior of the system components involved to realize the scenario of the find_a_dealer use case is shown in Figure 3. This sequence diagram depicts the message flow starting when a wireless client logs on with the intent to search for a dealer. Figure 4 shows the flow of activities as a client requests information from the dealership domain. The flow of activities proceeds between the wireless client, the Internet portal, the dealership domain and the information hub. A layered application architecture enabling the behavior of the find_a_dealer use case for a wireless client is shown in Figure 5. This application view shows the access of a wireless client to the dealership data via a secured information hub located in the database services layer.

Application	Data	Infrastructure
System block diagram depicting the high level application architecture	Entity relationship diagram	System block diagram
Function tables for specifying the new functions defined in the problem statement.	UML class diagram	Technology diagram of the server farm infrastructure for the development and test environment
Use cases and scenarios, at various level of abstraction, for modeling the external behavior of the functional components of the architecture.	Data schema definitions	Technology diagram of the server farm infrastructure for the production environment
UML sequence diagrams to model the interactions between the external actors and the Information Hub of the E-Business System.	Data dictionary definitions	
Leveled component diagrams to model dependencies between software components of the architecture.	Use cases and scenarios for the data processes such as data abstraction and collection, data mining, scrubbing and cleansing.	

Table 4 Notations for modeling perspectives of an architecture

Data viewpoint

A sample of the conceptual data model of the entities and their relationships to support the find_a_dealer use case is shown in Figure 6. Figure 7 shows the logical model of the data view point of the E-business system which includes needed enhancements to support the find_a_dealer use case. A request from a wireless client is serviced by means of components of the business services layer and data retrieved from the information hub, which contains the legacy database system and new Oracle database. Services within the

information hub include dealer message services, and data regarding vehicle information services, the dealer inventory, vehicle features and vehicle pricing.

Figure 8 illustrates the intricacies of the data extraction process as data is requested from the data inventory. Data originating from either the legacy system or new Database must first be analyzed, mapped, scrubbed and moved to the relational database of the information hub. Afterwards, the data is forwarded to either the enterprise or application server.

Ref. No	Function	Category
R1.	Find_a_dealer	evident
R2.	Cleanse & scrub dealer locator data	hidden
R3.	Map the data within the Information Hub to access data	hidden
R4.	Find services, e.g. Weather update Traffic update News update Stock update	evident

Table 5 System function table

IT infrastructure viewpoint

The viewpoint in Figure 9 illustrates the physical IT architecture which encompasses the required enhancements presented in Section 2. It shows the wireless client accessing the dealership domain via the Internet and WAP server. While inside the domain, all clients are routed to the secured firewall area, and then switched to an integration hub. Once access is granted through the data integration hub, all object requests are retrieved via the information hub, as well as interfacing with the application, business, and database layers.

5. ARCHITECTURAL DOCUMENTATION

The project teams documented their project deliverables by following the Enterprise Architecture Blueprinting (EAB) Methodology (Boar 1999) using the templates available on the Wiley web site (www.wiley.com). The methodology recommends a format for the architectural documentation consisting of a set of sections. The deliverables of each of the view points, outlined in Section 4, were organized within these sections. The resulting IT architectures for each of the viewpoints were compiled into project folders as given in Table 6.

The methodology recommends a format for the architecture containing a set of sections for organizing

Project folder
Project planning document (format derived from IEEE 1058 Standard
System context diagram
Models, artifacts and application architecture (Team 1)
Application architecture and strategic plan for enterprise system management (Team 1)
Data model, and guidelines for corporate data standards (Team 2)
IT Infrastructure, and service level agreement and disaster recovery plan (Team 3)
Outline of presentation slides
Peer review forms (inserted later since these were submitted confidentially
Minutes of team meetings

Table 6 contents of project folder.

the deliverables. This includes representation schemes for modeling the views, and notational rules that prescribe naming and numbering conventions, and other notational rules that aid in systemizing the large number of deliverables of an IT architecting project. These EAB recommendations were followed within the prescribed structure.

6. DISCUSSION

The EAB models of the enhancements for the E-business system were used to update the Index Model for this system (of the manufacturer). Table 7 shows the matrix with column 1 containing the inventory before the enhancements, column 2 the principles presented in Table 1, column 3 the models of the enhancements, and column 4 the standards that were used for the project. Together with the EAB documentation for each of the viewpoints the index model summarizes the status of the IT assets in response to the request for enhancements given in Section 2. In order to gain the desired maneuverability from the IT architecture it is imperative that all the models are entered in the index model and that they are placed under configuration control. The index model offers management the ability to see in summarized form how a particular business initiative is implemented from the organizational perspective, and the three IT perspectives of infrastructure, data and application.

The case study was used for the team project of an elective course in a graduate program in computer information systems. The approach, incorporating the E-business system case study for the teamwork of the

Perspectives	Inventory	Principles	Models	Standards
Infrastructure	T1 line High Speed Multi port Hub (1x 1000) WinNT 4.0 server/client MS-BackOffice Enterprise (unlimited) MS-Proxy-Server Enterprise (unlimited) Dell Power Edge Server dual P111 1000 MHz (6) Dell P111 Desk Top 500 MHz /w [3com IC](300) Fiber Optics & Cat5 copper shielded cable IBM mainframe firewall, web.apps, DB servers, network, and comm. topologies, middleware	Interoperability, Portability, Adaptability, Reusability, Wireless Technologies	Logical & Physical IT architecture models Supporting models	IEEE 1471 IEEE 12207.0 IEEE 12207.1 IEEE 12207.2 Develop operational standards
Data	Legacy DBs/ files Data models and dictionary Other Enterprise Information Systems DBs Customer Management System DB	Access to information hub, Access transparent to user Data captured at source Derivable data – data not Timeliness	ER diagram Logical model - data perspective Data extraction process	IEEE 1471 Data standards Relational SQL
Application	Customer Man. System Vehicle Order Man. System Dealer Acc. System Netscape Application Server Order Man.System E-Business System (before enhancements)	Scalability, Security, Off-the-shelf purchase	System function table High-level use case Sequence diagram Activity flow diagram Layered application architecture	IEEE 830 IEEE 1471 ISO12207 UML standards Internet standards
Organization	IT organogram Employee/departmental organogram Company policies Product-development process E-Business applications Organizational processes	Mission Goals Initiatives	System context diagram	IEEE 730 IEEE 828 IEEE 1220 IEEE 1471 ISO 9000 ISO12207 HR Policies & procedures

Table 7 Index model of IT architecture for E-Business System with enhancements

course, was first devised for term 1, 2000 and updated for term 2, 2001 using the current version of the same case study. The course is typically taken as one of the last electives in the curriculum when prerequisite coursework has been completed. Prerequisite knowledge for the course includes software development methodologies, data modeling techniques and notations, object-oriented techniques for modeling structure and behavior of systems using UML notation, and principles of data communication. Faculty chosen to teach such a course should possess strong organizational and pedagogical skills in order

to structure and direct teamwork for the project teams, and to allocate project requirements for the respective viewpoints to teams.

Students, while entering the course with the prerequisite course credits, had a range of experiential backgrounds. This was determined using a knowledge background and skills survey at the beginning of the course. Team leaders were identified cognizant of their academic credentials, knowledge of information technology and experience in project management. Students were challenged by the complexity of the problem statement and project specifications.

The requirements for the three viewpoints exposed students to a real-world situation to apply the concepts, methodology and techniques that were covered in this and earlier courses. Various techniques were applied such as analysis, abstraction, distinguishing between logical, physical implementation, and dealing with managerial aspects that formed part of the problem statement.

We found the involvement of the project sponsors valuable for both faculty and students. An additional benefit to students was the experience of working with IT professionals in the project context. This type of course could well be a core capstone course required of all graduating computer and information students. This case study presented faculty and students with a unique learning experience.

The authors wish to acknowledge the project sponsors, not identified in the paper, who made the case study available for the course. Appreciation is also due to the teams who participated in the two instances of the course for their involvement and diligence.

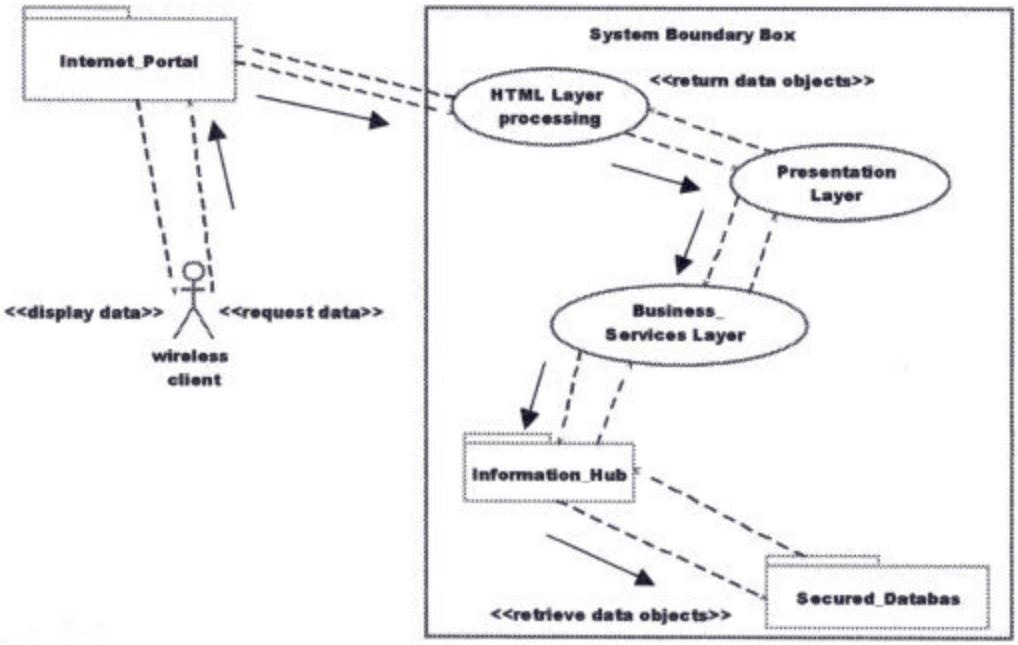

Figure 2 High-level use case for find_a_dealer

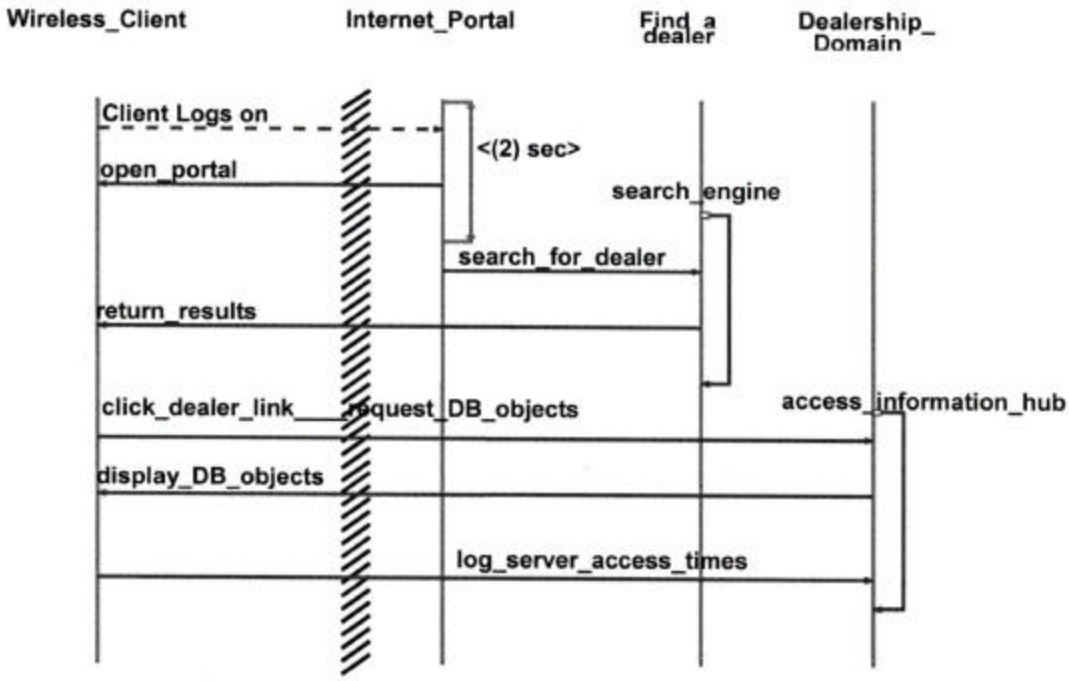

Figure 3 Sequence diagram of behavior of the find_a_dealer use case.

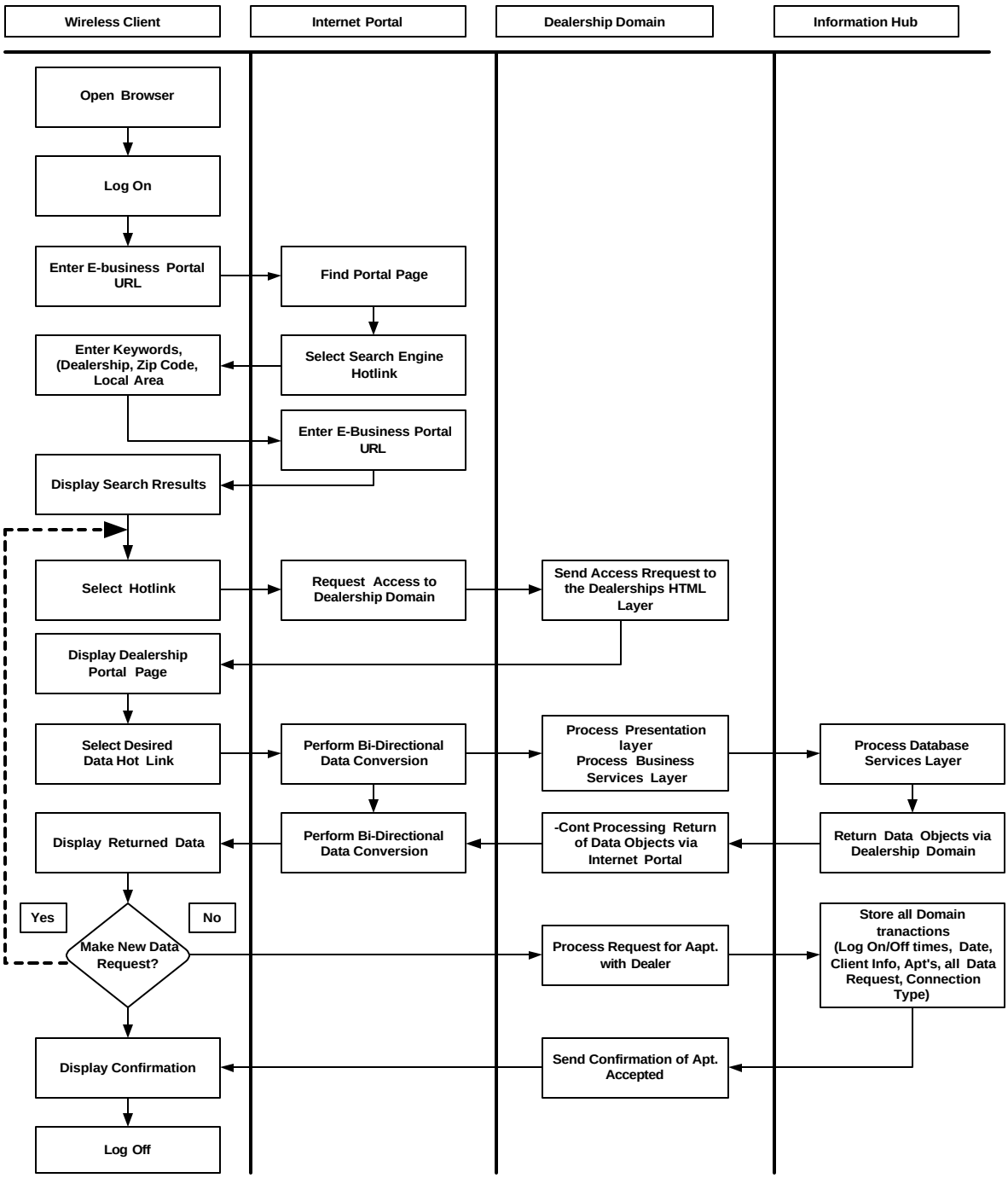

Figure 4 Activity flow diagram for client requesting information from dealership domain

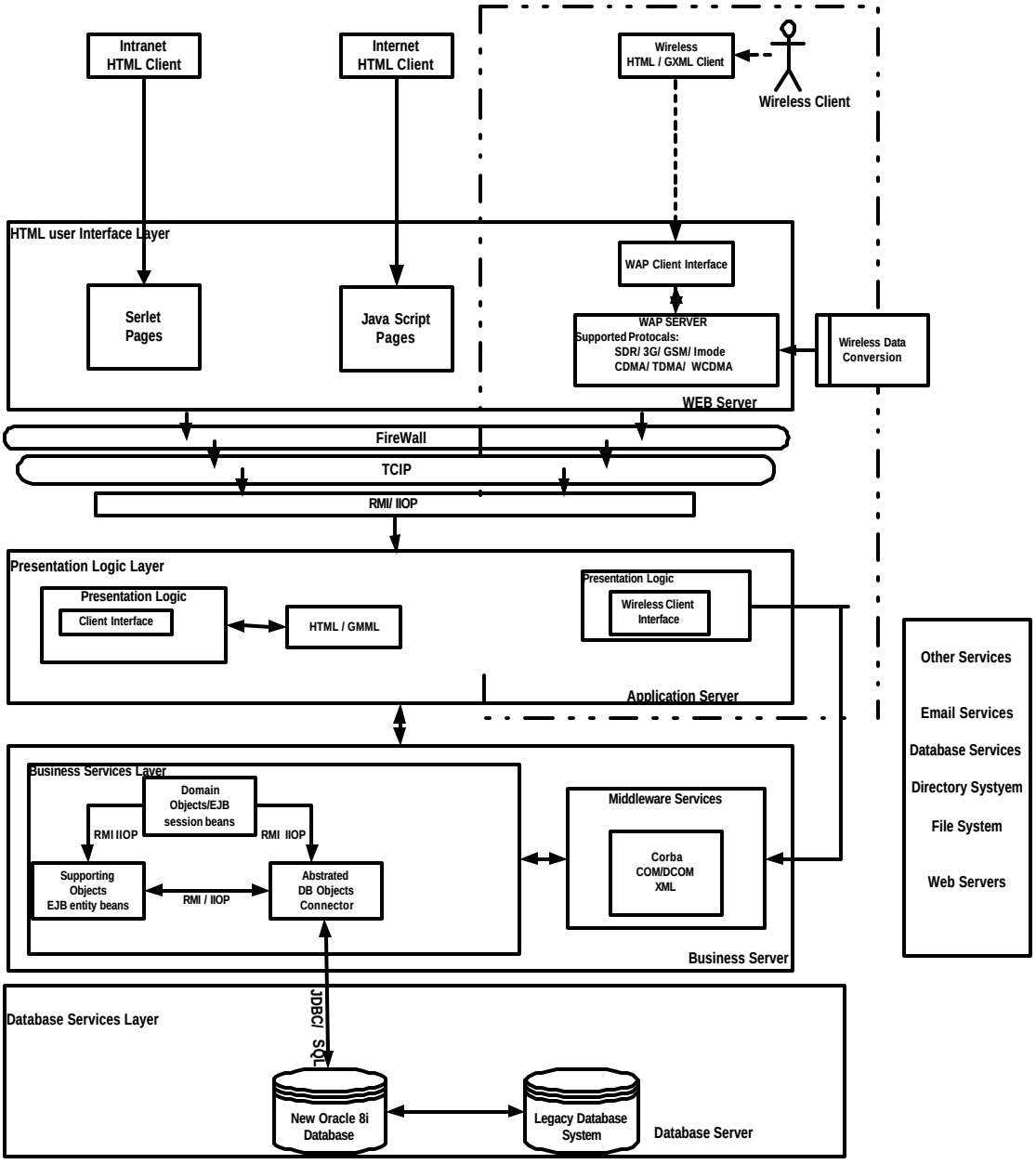

Figure 5 Layered application architecture

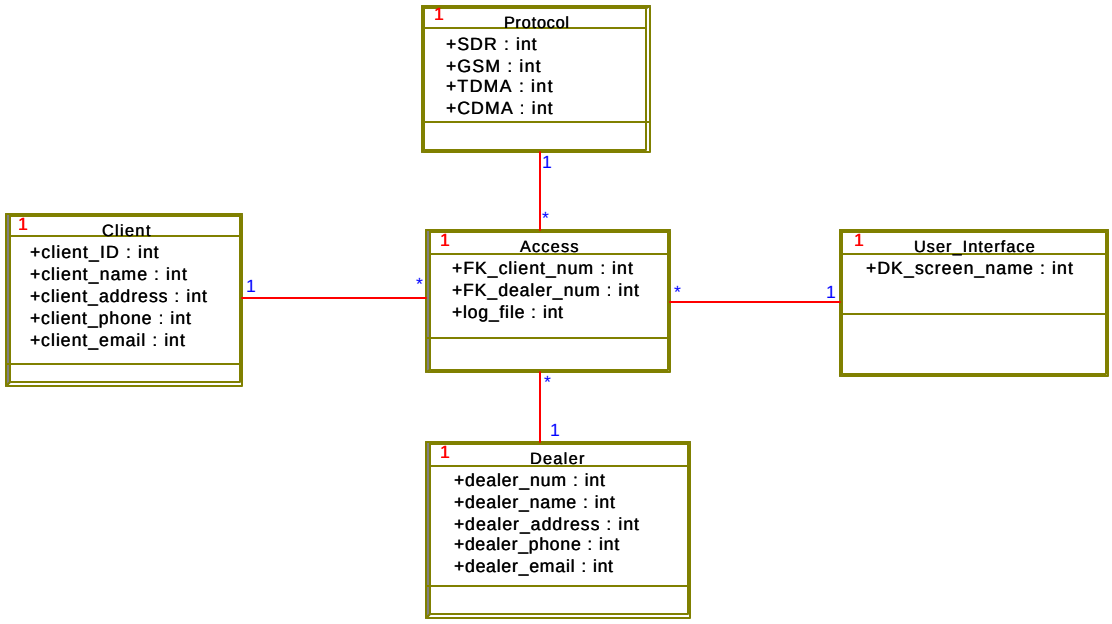

Figure 6 Entity relationship diagram of the conceptual data model for the find_a_dealer use case.

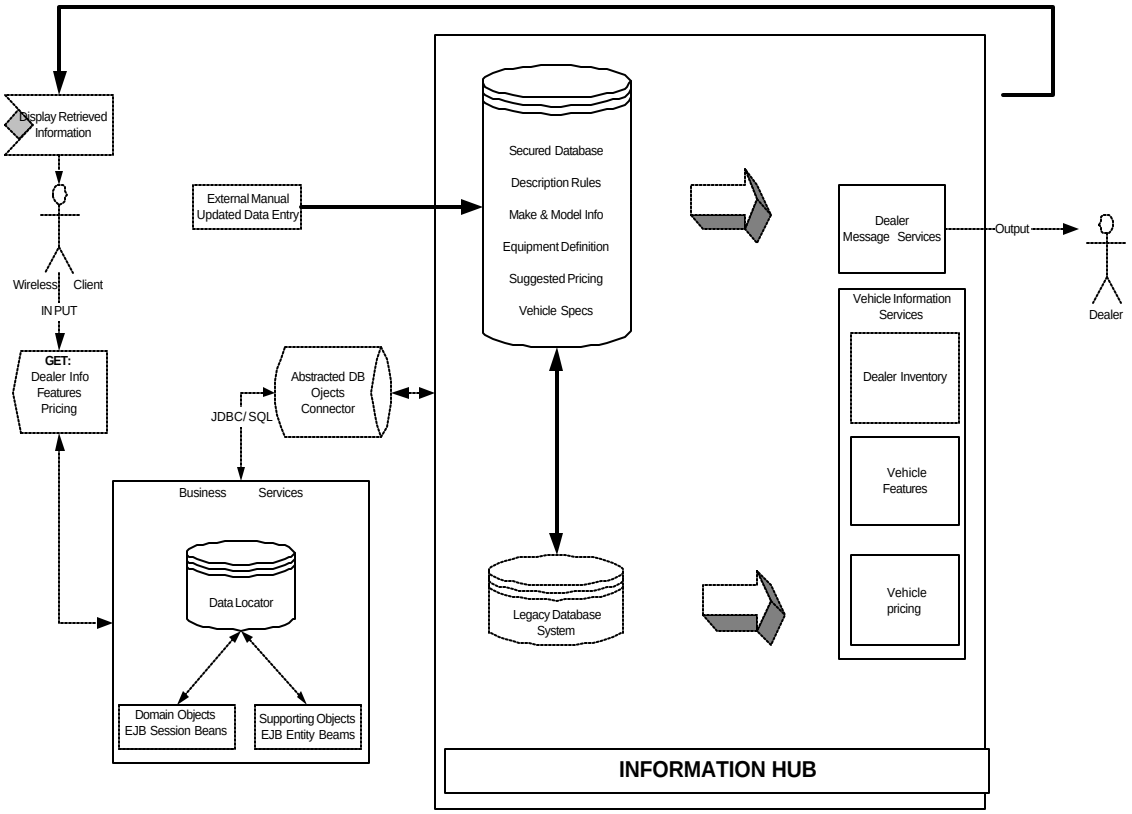

Figure 7 Enhanced data model for the E-Business system.

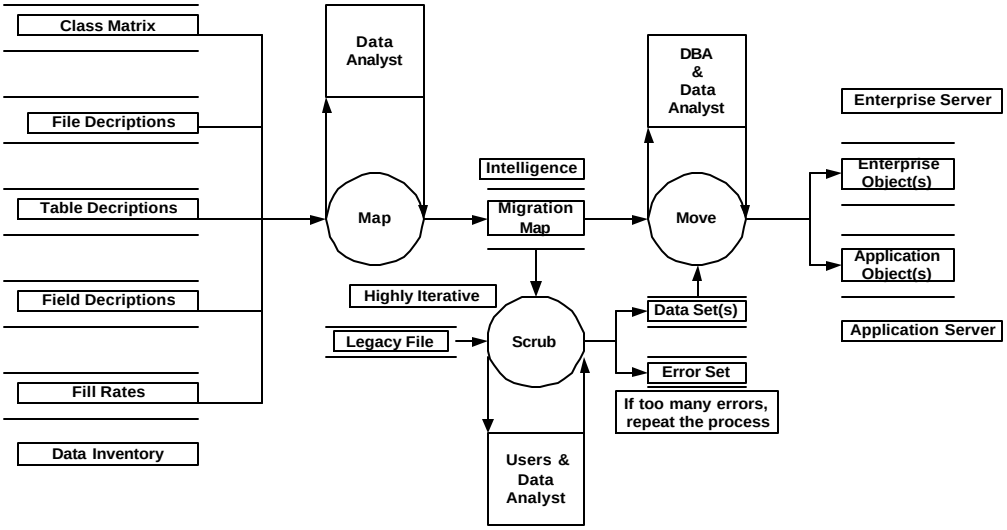

Figure 8 Data extraction process.

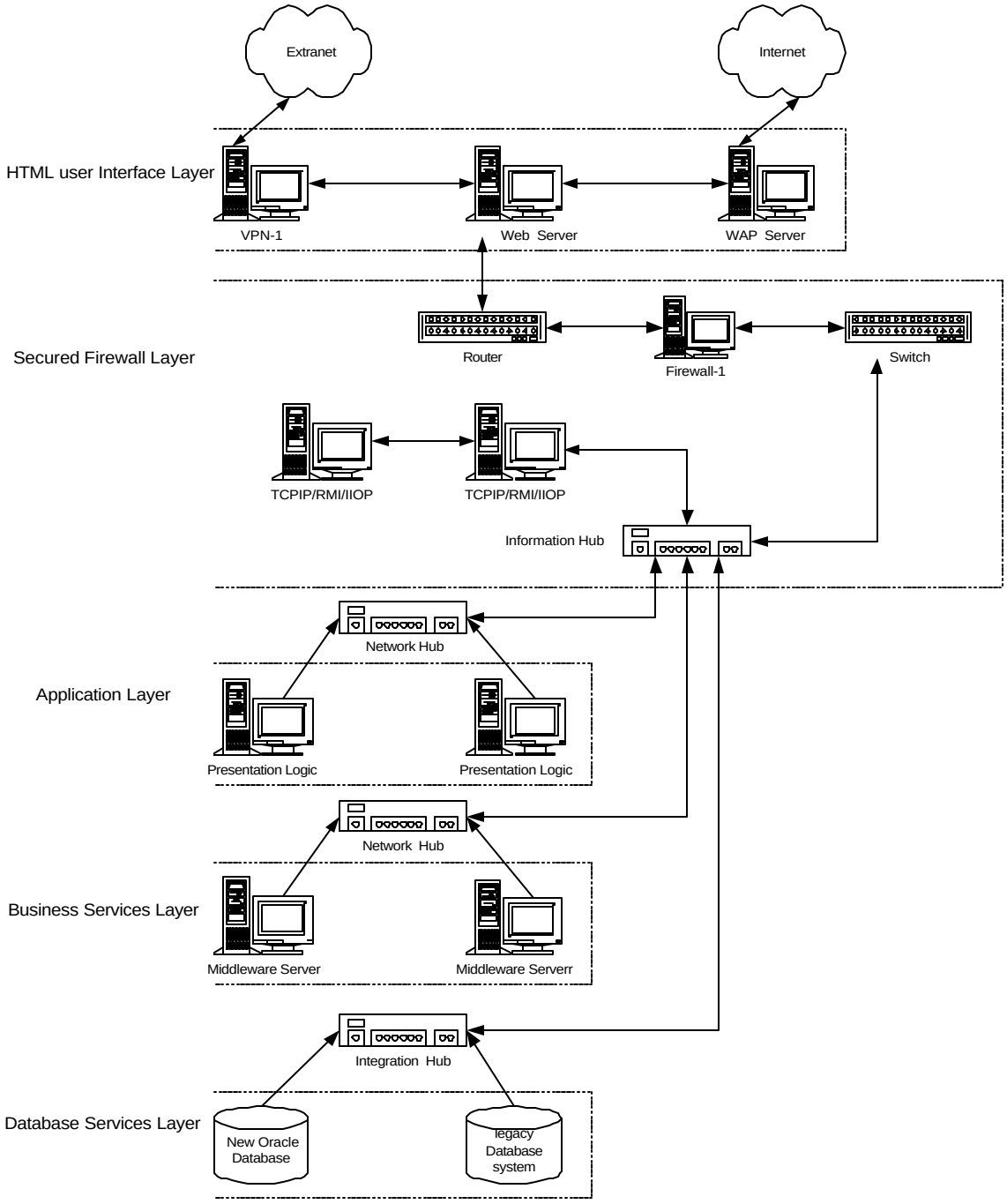

Figure 9 Physical IT architecture model.

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