

St. Cloud State University

RFID Shopping System

Senior Design Project (Fall 2011)

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Table of Contents

Introduction.....	3
Problem Statements	5
Project Description.....	6
Design Specification	7
System Overview	8
System Implementation	8
Slave System Block	8
Master System Block	11
Local Server Application	11
Database Design and Integration	14
Web Implementation.....	15
Conclusion	15
Tables.....	16
Figures	17
Figure 1 : Network Communication Topology	17
Figure 2 :System Block Diagram.....	17
Figure 3: RFID Tag Reader Diagram	18
Figure 4 : Master System Block.....	19
Figure 5 : ADO.NET Architecture.....	20
Bibliography	20

Abstract

With the shift in lifestyle of human beings, the needs of humans have dramatically changed; diversified products and proper product promotions must be provided to meet the demands of the customers. People are more concerned about the products they are buying and managers are more concerned about the sales pattern and demand supply of the products. This project presents a revolutionized shopping cart that utilizes radio frequency technology to go beyond traditional shopping cart and provides autonomous scanning system that displays price and complete description of the items on a high resolution screen attached onto the cart. The entire system is backed up by local server application driven by database server which allows efficient inventory management, product sales analysis for logistics purposes. And the system is accessible via internet and smartphone, so the system is available anywhere.

Introduction

Shopping has been a global phenomenon. With increasing human needs more departmental stores and competition between them is increasing in the global market. Minor details are also taken into consideration while providing best shopping experience to the customers. Huge investments in terms of assets and manpower has been made in order to manage the entire shopping system. But the technology that drives the shopping system is still primitive; where a customer have to take products to cashier in order to check out. There is always an intermediate factor between the customer and the company. People still have to stand in long queue for their turn for checkout and customers have to call sales associate to get more information about the product. Addressing the need of more reliable system, we come up with

idea of “RFID Shopping System” which uses Radio Frequency Identification which would be able to perform a self checkout shopping experience without any need of any human assistance, hence increasing customer shopping experience satisfaction.

Besides this Inventory management also plays a very crucial role in success of business organization. The way they manage the flow of products from manufacturers to customers is very important and the system helps to track down the mobility of the popular goods. If the product shortage occurs, customer will immediately turn to other supplier and hence miss a potential sales opportunity. With the help of data mining technology we can analyze the sales pattern of customers, which will help as main basis for sales analysis and warehouse control.

Hence our main objective from this shopping system would be to read tags from the products, provide detailed information about the product to the user, assist customer on complete self checkout system, and provide complete web interface. Nevertheless the shopping system also supports the management by providing logistical data about product inventory, sales flow and other information, which gives scope on datamining on customer shopping experience.

Problem Statements

When analyzing the operating model of product flow of a company, it can be found that the whole process of sales heavily depend upon the information user have about the product and availability of the product, which are two of major pitfalls of traditional shopping systems. Hence we tried to address the following bottleneck of the traditional shopping systems

- (1) **Complete Self Checkout System:** The system that's currently prevalent in the market till the date is more dependent on a sales associate to help you when you need assistance regarding the product. And in the case of Point of Sales Systems (POS) you still have to be in line to checkout.
- (2) **Inventory Management:** Due to lack of infrastructure in inventory management, company is losing sales percentage and degrading the overall goodwill of the company. When there is high demand of certain product, due to ineffective inventory management the company is not able to make profits on their sales. From research it has been confirmed that the company makes highest revenue on popular items. (Alp Ustundag)
- (3) **Lack of Shopping Services:** Traditional shopping system hasn't been able to provide a pleasant shopping environment. People want pleasant environment to make decision to buy products. They don't want to wait for available sales associate in line to get information about the product. The whole shopping experience is totally dependent upon the mood / attitude of the sales associate present at the location.

- (4) **Lack of Web Implementation** :People are not able to backtrack their buyings in cases they want to get more information about the product. But with web implementation, they can track their products whenever they want.
- (5) **Bar Code Technology**: Barcodes technology used in today's market are quite ineffective because it needs to be scanned facing the reader at an angle. And there is high probability of misread than compared to RFID. (National Barcode)

Project Description

Addressing all the problem states seen in the current scenario the main objective of our project is to make a system which can read tag attached to the product, perform a look-up on the particular tag and give information about the product and complete the point of sales checkout. The system design should be able to be implemented in real world scenario and the system should be autonomous. The whole system, from one end to another should work without need of any human assistance. And the system should be able to communicate with the customers by implementing various possible medias.

It should be able to monitor all the shopping activities by different shoppers within a particular range. The system should consist of single main with multi slave system implementing wireless protocol. And the database implemented for this project should be robust, which can be accessed using other protocols and can handle large amount of data.

It should be able to track current sales pattern of a customer to give relative feedback about various promotional offers available regarding similar product.

Design Specification

- The system should be able to read product information.
- The system should be able to get information about the product and keep track of inventory.
- It should be able to keep track of inventory of product and perform data-mining on the user choice preferences.
- System should be able to handle multi user environment, where more than one enters product in cart.
- It will function in home environment temperature (60 degree F - 90 degree F)
- Slave system should consume low power for better battery life and also display battery status and should have recharge mode as well.
- The slave and the master system should be able to communicate within in close environment.
- Slave and Master system should be able to communicate using wireless technology.
- Entire system should be backed up by remote database.
- GUI Application and API's should be accessible to the product information.
- The product should keep inventory of what the customer bought store in database.
- The Product should be cost effective and feasible.

Considering our design specification, we came with possible solution that can be implemented in this project to achieve goal of out project.

[TABLE 1]

System Overview

Our system consists of a master and a slave system. Slave system is attached to individual carts and master system is connected to the local server computer, which is connected to remote database. When the shopper scans his/her person ID using the card reader, it checks the status of the shopper in the database and starts the system. Whenever any product is added in the cart, the RFID reader reads the tag of the particular product and sends the information to the local computer via wireless communication. The local computer performs a look-up for the particular product and retrieves necessary information of the product from the database. When the customer is ready for checkout, customer slides his/her credit card and can perform his/her checkout easily, without any assistance of any cashier. Besides providing ease on shopping experience to the user, this system also helps in inventory management. Inventory management is controlled primarily by software on the local server computer which acts like a major block for information exchange. And using datamining tools we can create datamodels for specific user groups, which will also filter out related products a user might be interested in.

System Implementation

Slave System Block

Each Slave System represents a shopping cart. All components added to Slave System are designed to be added onto shopping cart. The slave system consists of these main modules: Microcontroller, Touch Screen LCD, RFID Reader, Magnetic Card Reader, Wireless Communication Module, FM Receiver, Speakers, Microphone and External Memory.

PIC18F4455 microcontroller is used to control operations performed by the slave system. PIC18F4455 microcontroller is a 40 pin high performance USB microcontroller with nano Watt Technology. All modules of Slave System communicate to each other through programmed microcontroller. Some features of this microcontroller include 10 bit high resolution Analog to Digital Converter that is used to display the percentage of battery level of the system on LCD. This feature will let the user know how much battery is left before the system shuts off or needs recharging.

One of the main modules of Slave System is Touch Screen LCD. This feature enables customers not only to see the necessary information but also select desired options. Options vary from displaying battery level of the system to payment by credit card. Programming of Touch Screen is done by microcontroller that initializes libraries and functions used by the Touch Screen. The complexity of Touch Screen might require the use of different microcontroller in the future design stage.

RFID reader module is used to detect items that are being put inside the shopping cart. It comes with an antenna designed to identify RFID tags. Tiny RFID tags are attached to each item being sold in the store. These tags include a tiny built-in circuitry involving small antenna. Antennas available on both RFID tag and the reader enable sending and receiving signals by both modules. Once the reader detects the item put inside the cart, unique RFID tag number is decoded for identification of the item. Operations performed using these unique numbers is up to microcontroller that receives them and performs necessary operation.

Since every member of particular store is given a member identification card (similar to Sam's Club) Magnetic Card reader module is implemented to identify member ID card. Slave

System starts with swiping the ID card through the magnetic card reader. Member ID data string is then sent to microcontroller for further operation. This same magnetic card reader module is used for accepting payments to finalize transactions. This feature of slave system allows customers to pay for items inside the shopping cart not having to wait for long lines or even taking items out of the cart for scanning.

To enhance shopping experience, our Slave System includes FM receiver. This simple module enables customer to pick desired FM station to listen to while shopping. FM receiver has an audio 3.5mm audio input jack attached for headphones. In future development, we might replace the headphone jack with wireless Bluetooth. Since customers might have questions or be in need of assistance regarding variety of issues, our Slave System also implements wireless module of communication. Simply with a press of a button, each customer is able to reach out to customer support branch of the store. Microphone and small speakers attached on the shopping cart will let the customer talk and hear the person helping to resolve any possible issues. There is a fair level of logic and a few other modules involved in making this feature work without interferences and effectively. Since voice signal coming out of microphone has a very low gain, amplifiers and filters are used to send and receive voice signals clearly. Wireless module is described in more details in later section.

Another added module is external EEPROM memory that stores all items that are currently in cart. Since each scanned RFID tag decodes as a 96 bit number, the use of external low cost EEPROM is essential. This feature reduces unnecessary data from been transmitted to master system and storing important information on the slave system itself. Once EEPROM is initialized and set up to use, reading and writing commands are easily implemented in the code. EEPROM utilizes fast I2C data transmission connection to microcontroller and keeps stored data

intact in the event of power outage. Writing and reading from EEPROM memory is done at higher rate by I2C protocol. Easy connection of I2C also is an advantage that employs only two pins.

Master System Block

Master System Block acts like heart of our project, because it is the central hub for all the slave systems. It processes data from all the slave systems connected in the system and also connects to the local server application in the system. Our master system block consist of wireless module to receive data from the slave systems, microcontroller to process data and local host server to act as connector to MYSQL Database.

Wireless moduel in the master system is responsible for receiving data from the slave systems. Since this sytem is multi slave system where more than one carts are being active at the same time, we have to make sure we design star network topography so that there is no data collision while perfoming multislave communication network. The data received by the wireless module is passed to the microcontroller which processes the incoming data depending upon the protocol used and handshaking protocol established between the master and slave system.

The processed information is sent to Local Server Application which is main core of our project which performs a lookup on the user data on the database and returns required information about the product or user. Beside that Local Server Application is also responsible to maintain data integrity in our database sytem.

Local Server Application

For desgining our local server application, we used C #.NET. The main reason for choosing C# over other programming is C#'s support with .NET Modules. Though both C# and

Java are strongly styped and object oriented, C#'s vast resource with .NET modules was more robust than using Java. And with the help of Visual Studio IDE, designing the graphical user interface part for the local server is more easy and efficient.

Local Server Application would basically have two mode of operation,

[a]. Administrator Mode (Manager Mode)

[b]. Limited Mode (User Mode)

[a]. Administrator Mode

This is the top level mode in the program interaction with database and microcontroller. Theoretically under Administrator mode, user can control all the details of software configuration. This mode is also used for system debugging mode. Access to this mode is only granted via password at the welcome screen. Various functions that can be accessed via administrative mode are :

- Database Setup

This gives the option of first time database connection with the remote server. This function will basically recreate all the tables required for the system to work. This function is only applied when a new system installed.

- Database Connection Configuration

This sets up connection port with the local database used or remote database system used in the system.

- Backup Configuration

If we want to backup our server backup datatypes to a SQL file. This function will allow to make backup of our datatypes, this will help will recovery of our database in case of accidents.

- Exporting Data to Excel

This will export the data in the table to .xls format so that our entire database can be used via other applications as well.

- Add Users

This will allow to add users in the database. While adding users, each user is assigned a particular Username, Password. In the Add User dialog box First Name, Last Name, Address, ZipCode, State, Telephone, Email, Date of Birth are asked. Date Validation is also used so that entered data are within the scope declrated in our database hence maintaining data integrity. Once the user enters all the data, if the User clicks “Add” button, the information is stored in the server database. Hence that user is able to perform any transaction in our system. UserID for each user would be the magnetic card reader member number.

- Edit Users

Similarly, users can be edited once the information is in database.

- Add Products

Similar to add products, Administrator can Add Products new to database.

- Edit Products

If user needs to edit products, user can edit products using this function of the program.

- Forced Manual Transaction

When ever there is a checkout in the system, the system will keep record of all the items bought by the user, so technically it will keep a record in Transaction Table under specific username.

- Test Mode

This mode is more for debugging purposes.

[b]. Limited Mode (User Mode)

This is the general mode of operation for the server to run. In this mode, the server is in the state of receiving data from the microcontroller. If there is data in the receive buffer, it receives the data and depending on the handshaking protocol used, it will retrieve the product information or if the user checkout performs the transaction.

Database Design and Integration

For this project we will be dealing with large amount of data so we plan to implement relational database technology and choose MySQL because of it's high performance, high reliability, and ease of use. Another reason for choosing MySQL over other database managements is it's easily integrable with new generation of applications built on LAMP stack (Linux, Apache, MySQL, PHP/Perl/Python) (MySQL)

While designing our databse our primary goal was to maintiain data integrity using relational tables by means of data normalization. Normalization is the process of efficiently organizing data in a database. (Mike Chapple)

For the connection between the local server program running in C# and MySQL database MySQL connector is used. Connector/NET enables developers to easily create .NET applications that require secure, high-performance data connectivity with MySQL. It implements the required ADO.NET interfaces and integrates into ADO.NET aware tools. ADO.NET provides consistent access to data sources. [Figure 5]

ADO.NET and the XML classes in the .NET Framework converge in the Dataset object. And DataSets are used in our local server application. (Microsoft)

Web Implementation

For the web implementation of the project, PHP 5.3 (Current Stable) is used as hypertext pre-processor to get data from the Database server. And XHTML (eXtended HyperText Markup Language) and CSS (Cascading Style Sheets) is used to draw websites to display the userdata. As in server application program web page has two mode of access, Admin Mode and Limited Mode. In Admin Mode, user is able to Add Products, Edit Products, Add Users, Edit Products.

But in limited user mode, user is able to see his/her personal transaction record log.

Since the data is in the remote server, smart phones can be also used to access the userdata using various connectors available in the market.

Conclusion

Considering the current shopping systems available in the market, we propose better shopping system considering the manforce, space and time utilization factor. Our project demonstrates a smart electronically powered autonomous shopping sytem with added capabilities

of smart product tracking capability using datamining technology with enhanced web interface added. The sytem provides practical solutions to the encounded problems statements currently present in the market. This system will reduce the extra costs spent freviooug on inventory management and also help to get more accurate data on the item inventory to eliminate problem of product shortage by providing realtime data analysis. This system will also broaden scope for more data mining analysis by providing huge data regarding customer choices. And with the help of providing information media we can provide customers with more broader choices and make smart product choices to increase overall customer satisfaction.

Tables

Specification	Possible Solution
<ul style="list-style-type: none"> • Scan an item 	Radio Frequency Identification
<ul style="list-style-type: none"> • Provide Detailed Information about the Product 	Database Implementation
<ul style="list-style-type: none"> • Multi User Environment 	Master/Slave System
<ul style="list-style-type: none"> • Efficient Slave System 	Recharge Module, Battery Indicator
<ul style="list-style-type: none"> • Efficient Master Slave Communication 	Multipoint Wireless Network Topography (Star Topography)
<ul style="list-style-type: none"> • Program to track all the activities in the system 	System GUI Application
<ul style="list-style-type: none"> • Access user data via remotely 	Web Framework Implementation

Table 1 : Project Specification and Possible Solution Table

Figures

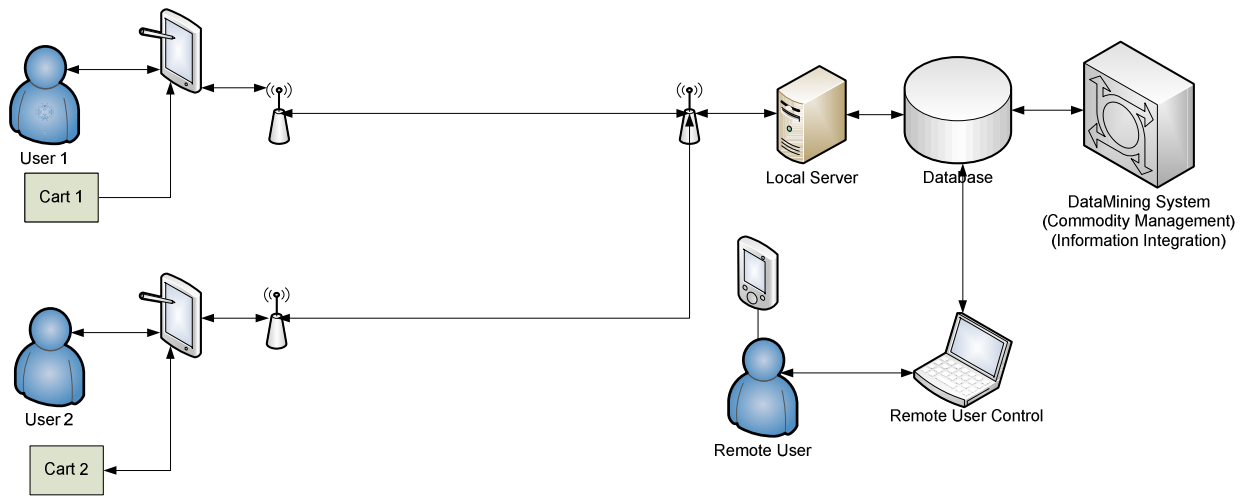


Figure 1 : Network Communication Topology

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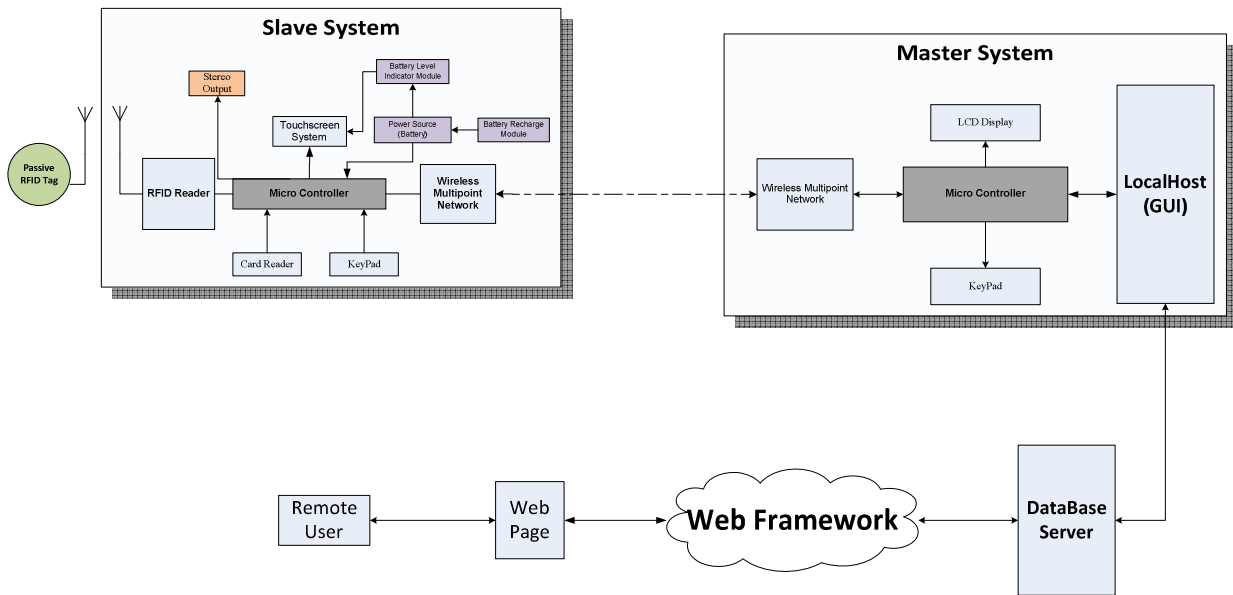


Figure 2 :System Block Diagram

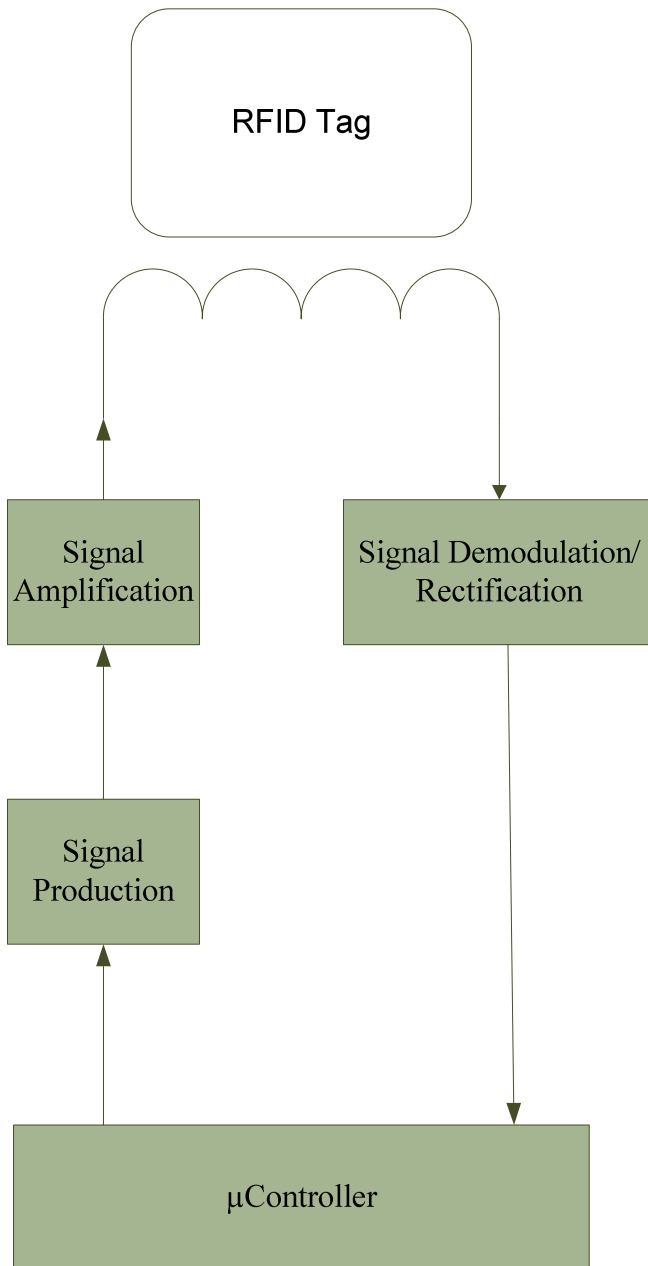


Figure 3: RFID Tag Reader Diagram

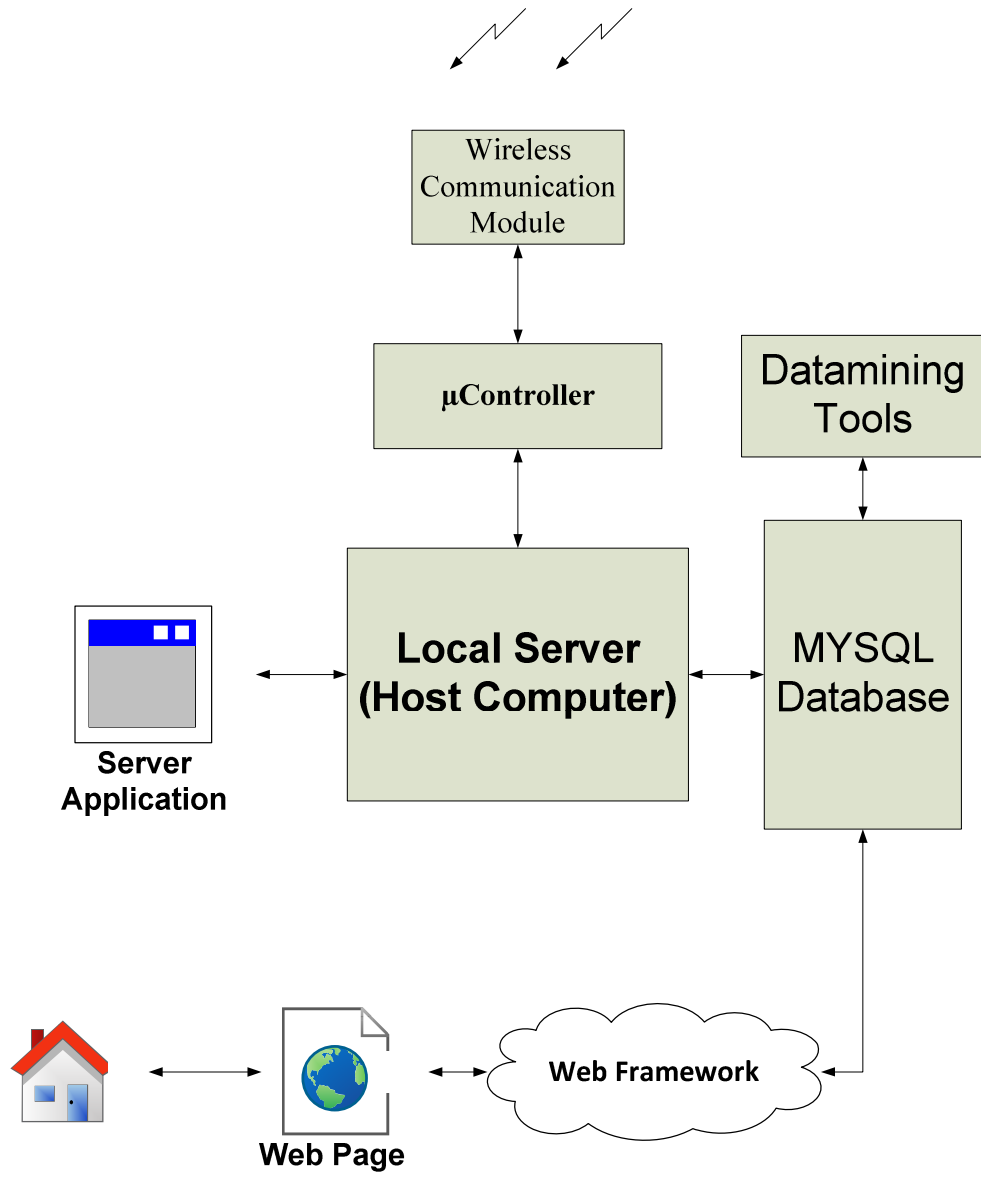


Figure 4 : Master System Block

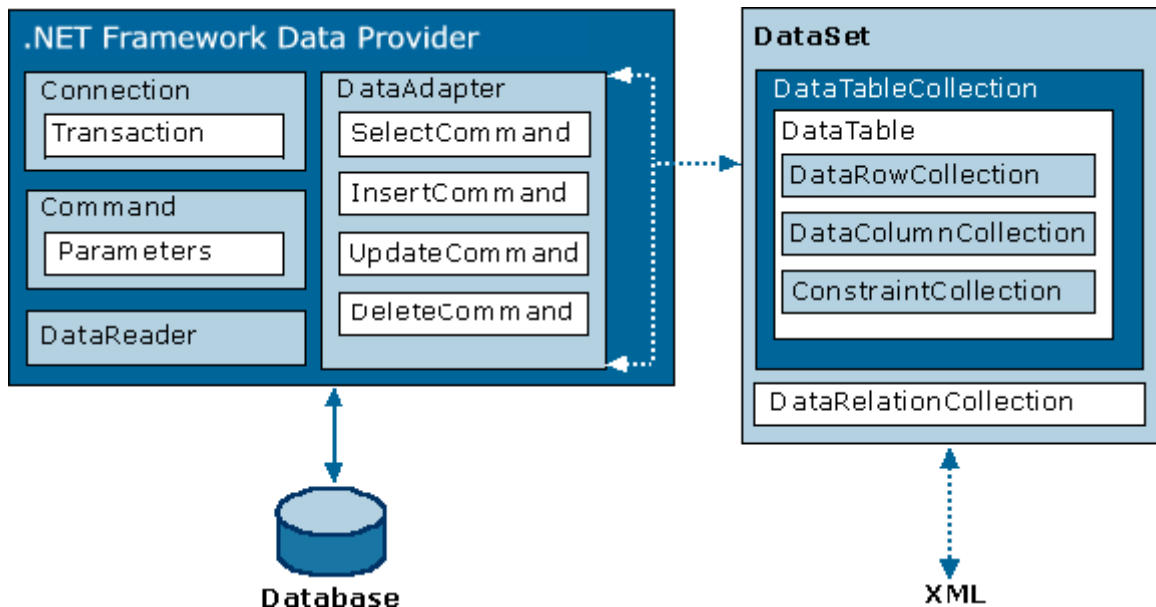


Figure 5 : ADO.NET Architecture

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