

Resource Monitoring: the Example of Network Utilization and Energy Efficiency Towards Green Communication

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Abstract Green communication is a necessity within the telecommunications industry. It has led many researches to come across ideas on how to optimize telecommunication to acquire energy saving. Most of these ideas targeted the transport layer of Network systems, while this paper targets the application layer and suggests a new dynamic mechanism to improve the network and energy efficiency of Location Based System (LBS) applications. The design is based on responding to the end user after sensing his/her device capabilities and available resources, such as battery, memory and internet speed. A simplified prototype has been developed in three tiers; the user interface (client tier), the web server (application tier) and the data base development (data tier). The developed prototype was tested and evaluated in three stages: (i) A pilot test measuring the systems functionality with limited number of users synchronised on the same wireless channel. (ii) A Data flow evaluation test measuring the efficiency of the new idea in managing the data flow according to the wireless connection speed. (iii) Assessment trials were conducted in critical situations where the user's mobile device was running out of memory and/or battery resources.

Key words: Location based services (LBS) • Data flow Management • Mobile Computing • Green Communications • Energy Saving

INTRODUCTION

The world has undergone a major revolution in Information and Communication Technology (ICT) since the last decade. This is mainly driven by the advancement and evolution of internet, Wireless communications and satellite, which has transformed our ways of life [1, 24]. For example, the information accessibility and the need of 'anytime-anywhere' connectivity have become requirements of daily life. Thanks to the advanced wireless and mobile networks that have become more than a medium for classical communication (voice and Short Messages Services) and their rich data link can transmit video, web browsing and other multimedia contents to the end user mobile device, while the user is moving from one place to another. However, 3% of the world-wide energy is consumed by the ICT infrastructure [2]. This high-energy usage has a great impact on global warming and is attracting more attention. Recent technological advancements in the field of wireless and mobile communications showed evidence of

possibilities to decrease carbon dioxide (CO₂) emissions by reducing the energy utilization. The official studies show that ICT productions contribute to around 2% of global CO₂ emissions, which is almost the same as CO₂ emissions of airplanes. Moreover, the mobile industry is growing at high rates. In 2020, the number of connections will be around 8 billion. Hence, both researchers and vendors need to guarantee that the growth in this industry must keep CO₂ emissions rates at the lowest levels [3]. These issues inspired new ideas how to optimize energy saving. Currently, the majority of research in ICT is focused on the protocols and devices in the core network [4]. This paper presents a mobile application design that contributes in minimizing the network utilization, which will also decrease the energy consumption and boost up the green telecommunications.

People have increased the use of mobile in terms of their lifestyle and occupational behaviour and there is a demand for delivering information to them according to their geographical location. As a result a system known as Location-Based Services (LBS) was developed by

integrating satellite navigation, mobile network and mobile computing to enable Location-Based Services [1]. Such a system combines the location information of the end user with intelligent application in order to provide related services [5]. LBS system has become popular since the beginning of this decade mainly due to the release of Global Positioning System (GPS) signals for use in civilian applications, like navigation systems in cars. However, the applications for pedestrians' LBS are still below expectations. This is mainly due to the challenges inherited from the components of LBS that have emerged along with the system development itself. For instance, GPS accuracy and signal availability are not sufficient for pedestrian users in urban environments with high buildings [6] and mobile networks' Quality of Service (QoS) could degrade due to the congestion created by having a number of users in urban areas. Moreover, mobile devices are still suffering from battery energy consumption, small memory size and low processor performance [7, 8]. Also, the LBS server is experiencing problems with managing the huge volume of information stored in the database.

The latter three aforementioned issues (mobile network, mobile device and LBS server) can be crucial when rich data (i.e. high data rate) are used in LBS, whether for improving the usability as a solution for not using the traditional maps on mobile, or as a normal demand for the need of multimedia contents by the end users. Since transmitting huge size of data consumes more energy, then we are in need for managing the data-flow.

Therefore, in this paper a dynamic strategy is presented in order to tackle these issues using Intelligent Resource Monitor (IRM). The main difference between the static and dynamic mechanisms is related to the size of data retrieved from the database and transferred from the LBS server to the end user over the wireless mobile network. The static one was introduced through a previous publication [9].

The novelty of IRM mechanism can be noticed in the way it manages the data flow according to the available resources. The basic concept of this mechanism is that when the end user requests the service; a powerful software program gathers information about the available resources of the mobile device. The system then makes a decision based on the status of the resources and decides whether to establish a connection with the LBS server to obtain the service or not. If the resources are sufficient then the IRM sends it along with the location information to the server, where another program receives it and decides on what size of data should be streamed to this particular mobile device.

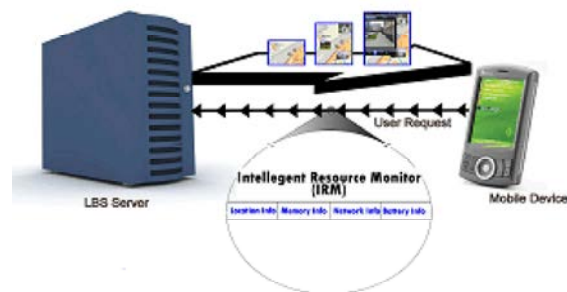


Fig. 1: Dynamic Zone-based Update Mechanism Using IRM

Table 1: The Five Categories of the Mobile Device Status, With Specifications

Available Resources Cat.	Illustrated Area Radius (Miles)	Supplementary Objects	Maximum Size (Mbyte)
Cat 1	0	Nothing	0
Cat 2	1	POIs	2.5
Cat 3	1.5	POIs & Images	3
Cat 4	2	POIs & Images	4
Cat 5	2	POIs, Images & Videos	5 + (5 for video)

This new dynamic mechanism is much more powerful and intelligent, as it prevents any loss of data. It also provides a compromise design, which contributes to better utilisation of the network bandwidth, as well as the mobile device resources, which results in enhancing the overall efficiency of LBS systems and contributes to green telecommunications.

Intelligent Resource Monitor (IRM): As illustrated in Fig. 1, the IRM carries the device's available resources from the mobile side to the LBS server, the server then responds by sending information accordingly. The size of data which is sent back varies from time to time and from one device to another. For example, if the available resources are less than certain value (the Critical Level), then the server would advise the user that it is not possible to receive the service at the moment. Hence, this will save the end user's time, effort and cost. Conversely, if the mobile device's resources are above that critical level, then IRM mechanism manages the suitable size of data accordingly.

As can be seen in Table 1, the status of the mobile device is classified according to five categories. Each category has been defined according to the size of data which can be transferred from the server to the client. However, the size could be customized if needed according to the user's needs.

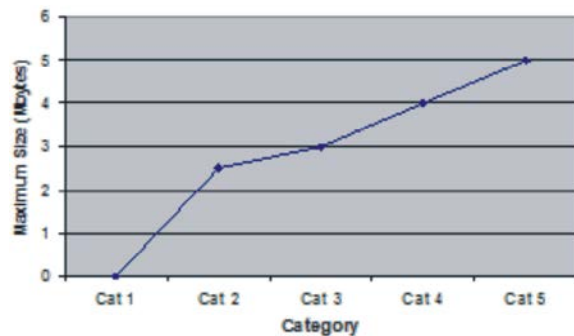


Fig. 2: The Higher the Category of Mobile Device, the Larger the Size of Data Received

The total data size which can be downloaded to the end user's device is equal to the summation of the map size for the given radius and total size of objects (POIs, images, videos etc.) within radius of the same area. For example, for 'Cat 1' category, no data could be streamed due to insufficient resources; whereas for 'Cat 5,' high quality objects could be streamed to the end users as there are sufficient resources to allow that. For other categories between 'Cat 1' and 'Cat 5,' the type and size of data which can be obtained varies accordingly (i.e. the higher the category the larger the size of data), as shown in Fig. 2.

As the concern of this research is LBS for pedestrian users, the researcher configured the system to collect data only within a two mile radius, but this area size could be customized if necessary (i.e. the system administrator can make the area smaller or larger). This size of zone can only be streamed over categories 'Cat 4' and 'Cat 5,' and is considered to be sufficient to provide the users with enough information concerning the surrounding area. Once the user is out of that zone, the information about the new zone will be acquired.

The maximum radius of the zone in category 'Cat 3' will decrease to 1.5 miles and the radius for category 'Cat 2' will be limited to only 1 mile. In such a way the end user will be supported with the most suitable size according to the category of the available resources of their mobile device.

Furthermore, the end users with the highest category ('Cat 5') are supported with supplementary objects such as images, videos and POI's. Each one of these objects is plotted on a GIS layer [10]. The first layer is the map itself, the second is the Points of Interests (PoI's) layer, the third is the images layer and the last is the videos layer.

IRM Application Usability: This section describes how this new mechanism could be used in real life, which has been demonstrated by building a simplified prototype using off-the-shelf software and hardware. More details about the system setup are presented later in this paper in the 'IRM Testing and Evaluation' section.

When the end user requires the service, they activate the IRM application on the mobile device. The IRM firstly presents a welcome message with possibilities of connecting to the server or exiting the application. The welcome screen then provides information about the application and describes the use of its functions.

If the user disagreed with initiating the connection link, then nothing would be done and the application would return back to the welcome screen, whereas if the end user agreed to connect to the server, another sub-program encapsulates the collected information along with the geographical location information (usually latitude and longitude) and sends it to the LBS server.

Once the end user selects the 'Connect' button, a group of four sub-programs within the IRM is triggered in order to allow information concerning the mobile device resources, as well as the location information to be collected. Following that, another sub-program is executed to make a decision not to connect to the server in case of lack of resources, or to allow the end user to choose between either initiating the connection link or aborting it if enough resources are available. For instance, if at least one of the three resources has been categorized in category 'Cat 1,' then a message box would be shown to the end user informing them that the mobile device currently cannot receive the service due to lack of available resources. Otherwise, if there are enough resources, the end user would be shown the results and informed that the gathered information is ready to be sent to the LBS server in order to complete the journey (Fig. 3).

At the server side, which is virtually separated into two servers (application and data servers), a de-capsulation process is applied on the received message, which is carried out by the IRM application server program, which translates them into a query command using Structured Query Language (SQL) [11], which can be understood by the Database Management System (DBMS).

The DBMS then determines the category of the received resources (Cat 2, Cat 3, Cat 4 or Cat 5) and retrieves the related data from the database within the given radius for that particular category. The application



Fig. 3: Screen Shot of the IRM Application Asking Users if They Agree to upload Information to the LBS Server

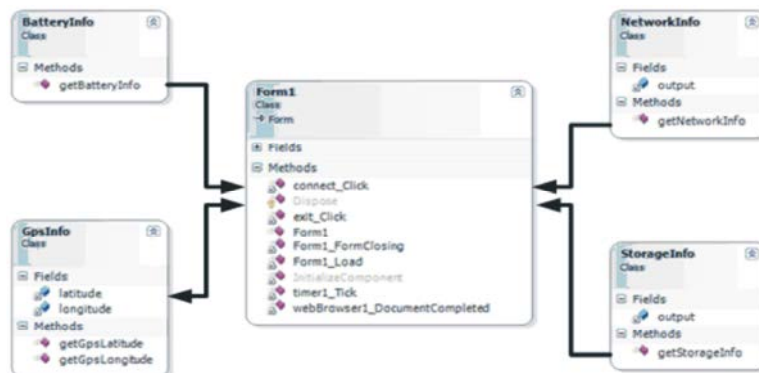


Fig. 4: The Programs (Classes) at the Client Side of the IRM

server then receives the results of the command query back from the database server in a Data Set format and converts it into a WebMap format, which is applicable by the end user.

Software Architecture of IRM Application: The actions displayed in the flow chart presented above were implemented based on the 3-tier technology [12], which consists of Data, Application and Presentation tiers. The database server represents the data tier, the web server represents the application tier and the client device represents the presentation tier.

Three main challenging tasks were successfully addressed during the development phase of IRM application. The first was developing the user interface, which is used at the client tier; the second was the web service development, which is used at the application tier; and the third was the database development at the data tier.

At the client tier, the interface program was developed using C Sharp (C#) programming language [13], which belongs to the family of Object Oriented (OO)

Programming Languages [14]. This language was chosen because of its strength in dealing with hardware, as well as 3-tier software models [13].

At the application tier of this technology, the IRM application utilises the Internet Information Service (IIS) [15] web server, in order to be the mediation link between the end user and the data. The main function of this tier is to transform the data which is retrieved from the database into meaningful and user-friendly interfaces.

The third tier of the IRM application is the data layer. It is the place where all of the required information is stored. This database is managed by Database Management System (DBMS) [16], which is the software responsible for adding, deleting, amending and managing the database tables. IRM uses Microsoft® SQL server [17], as it is one of the most reliable database engines.

The Client-side Software (Presentation Tier): At the client side, four main programs were developed (Fig. 4). These programs are:

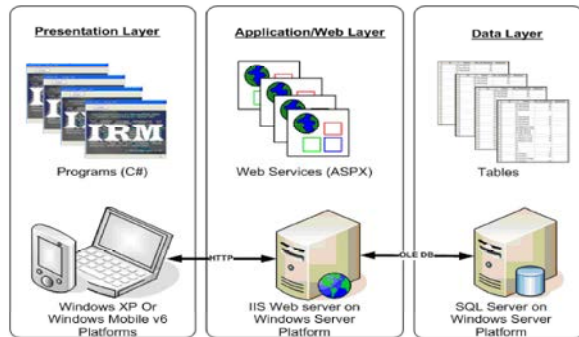


Fig. 5: IRM Software Architecture Based On 3-Tier.

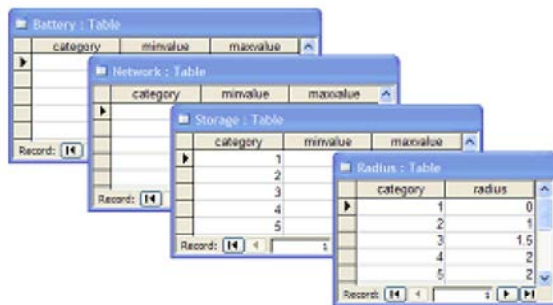


Fig. 6: The Four New Tables Added to the Database

Network Info: This program searches the mobile device for all available network interfaces and then filters them to get the one which the end user is utilising. The network information contains the highest possible connection speed.

Storage Info: This program uses the operating system's resources to retrieve the free available space on the hard drive.

Battery Info: This program retrieves the remaining power of the mobile device battery.

GPS Info: This program analyses the NMEA information received from the port that the GPS receiver is connected to (usually by Bluetooth), then the program retrieves the required information, which is the latitude and longitude of the GPS receiver.

The main program (Form1) is the responsible class for calling the other four programs. When the end user clicks the 'Connect' button, the method 'Connect_Click' starts collecting the device information. The three programs (StorageInfo, BatteryInfo and NetworkInfo) send data to the main program (Form1) without any input (argument), whereas the GPSInfo does need an input in order to return an output. In other words, the main program (Form1) retrieves the NMEA string data from the GPS receiver and

sends it to the 'GPSInfo' program (as input), which analyses it and deduces the location (latitude and longitude) and then sends it back to the main program.

The Web Server Software (Application Tier): At the middle tier (Application Server), another piece of program was developed. As the main purpose of this layer is to translate the language between the client and the data server (Fig. 5), the program basically performs two main functions: firstly, it receives the mobile device resources via Hyper Text Transfer Protocol (HTTP) [18] and saves each one in an individual variable. Then, it tags these variables to a query request and sends this to the database server via Object Linking and Embedding (OLE) connection [19].

Subsequently, it receives the results set from the database and arranges the suitable services according to the mobile device's available resources. Then, it creates the final web map with all of the information retrieved from the database and finally sends it back to the client.

The Database Server (Data Tier): At the third tier (data tier), a large number of tables were arranged. Those tables store all the required information that needs to be sent to the end users. Similar to any GIS database, the IRM database contains different kinds of tables. Some of them are fundamentally important and are used frequently and others are lookups which store peripheral information such as captions and labels. The main contribution of IRM at the database side is adding new tables to the GIS database. Those tables relate to the mobile device's available resources in such a way as to compare the data coming from the client with the stored data. Another way to achieve this purpose could be performed without the need to add any new table to the database, but in this case more coding should be written at the application server. In this case the system administrator should also have access to the source code every time a modification of the categories is needed. This is not practical, so having them in the database is easier for management and administration.

In order to simplify this concept, four tables were created: Radius, Battery, Network and Storage (Fig. 6). The purpose of these tables is to store and retrieve the category of the mobile device resources. The table 'Radius' links each category with the size of geographical area that needs to be retrieved. The other three tables link the category with the minimum and maximum values of each type of resources. For example, if the remaining battery power is 30%, then the device status will be classified in category 'Cat 3.'

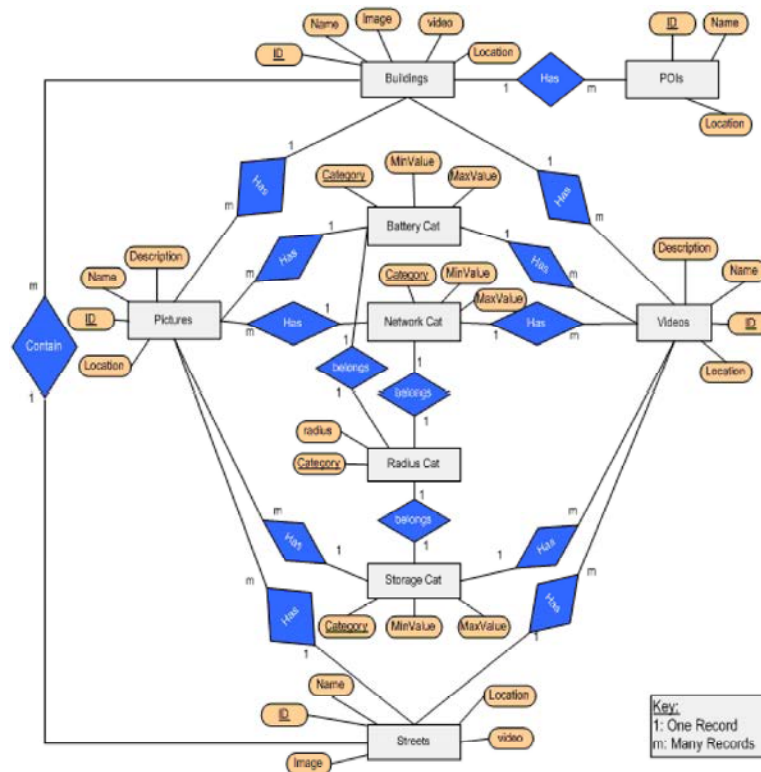


Fig. 7: Entity Relationship ER Diagram Describes the Integration of the New Added Tables with the GIS Database

Table 2: Categories of Mobile Device Available Resources

Category	Battery Levels (%)	Network Levels (KB/s)	Storage Levels (Mbytes)
Cat 1	Less than 10	Less than 128	Less than 2
Cat 2	10 to 30	128 to 255	2 to 2.99
Cat 3	31 to 50	256 to 703	3 to 3.99
Cat 4	51 to 70	704 to 768	4 to 6
Cat 5	Greater Than 70	Greater Than 768	Greater Than 6

Each one of the mobile device resources was categorized in five levels, as can be seen in Table 2. IRM decides how big the size of data the end user's device can handle within a period of time according to this category. Hence, if the category-level of the three resources are higher than 'Cat 1,' then the end users receive information from the database according to their mobile device status.

In order to easily understand the relationship between those four tables and the existing GIS tables, an Entity Relationship (ER) diagram is shown in Fig. 7. This ER diagram shows only the part of the GIS database which includes the new tables. As can be seen, the tables are well-connected to the whole system. The tables Battery, Network and Storage provide the category level to the other entities of the database like the tables 'Video' and 'Pictures,' Hence, each row in the table 'Videos' has got a category linked to that particular video. So a mobile

device with lower category receives shorter and lower-quality videos and one with a higher the category receives the best video quality. This is also applicable to the table 'Pictures;' each picture is linked to a category. The table 'Radius' is connected to each one of the three earlier mentioned tables. This table stores the radii of the geographical area which has to be downloaded according to the mobile available resources.

These four tables are designed in a way that makes it easier for the Database Administrator (DBA) to change the system parameters and settings. For example, the DBA can easily change the area size to be 3 miles for category 'Cat 4' without the need to change any code, they just need to access the table and amend that particular row.

Hardware Architecture of IRM Application: In order to evaluate the IRM application, a simplified system prototype has been deployed using off-the-shelf available hardware components. As can be seen in Fig. 8, the following hardware elements were utilised:

Laptop Computer: Toshiba® Satellite® with Windows Vista® operating system and Intel® Core™ 2 Duo Processor T5800 (2.0), supported with 2048 MB (1024+ 1024) DDR RAM (800MHz).

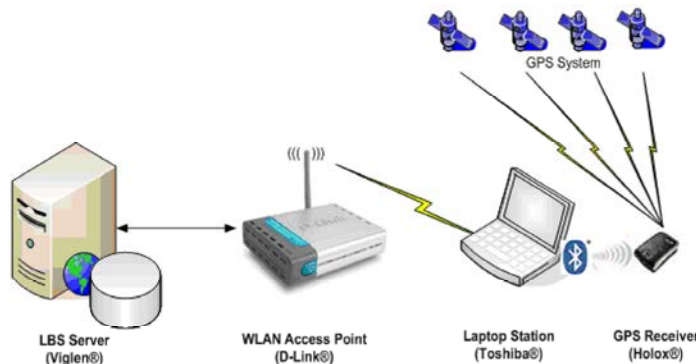


Fig. 8: The Hardware Used to Compose the IRM System Initial Prototype

GPS Receiver: Holox® with 32 channel GPS engine and Bluetooth connection capability.

Wireless Access Point: D-Link® AirPlus Xtreme G (DWL-2000AP) 802.11g, which supports 801.11g (54 Mbps) and is backwards compatible with 801.11b (11 Mbps).

Server Computer: Viglen® with Windows Server® operating system and Intel® Core™ 2 Duo Processor 6300(1.86), supported with 2048 MB of RAM.

IRM Testing and Evaluation: This section of the thesis presents the testing and evaluation process of the IRM mechanism. Testing is one of the most important tasks in the development lifecycle [12]. It shows the strengths and weaknesses of the system. Therefore, five testing scenarios were performed during this evaluation process. These scenarios were performed in three phases:

Pilot Test: The first task of this phase was checking the basic functionality of the new IRM while one user only is connected. The second task was measuring the time and speed of retrieving the service while two users are sharing the same wireless bandwidth.

Data-Flow Evaluation Test: the aim of this test was to check how the IRM mechanism manages the flow of data according to the wireless connection speed.

Critical Situations Test: This evaluation was carried out to test the IRM application when the mobile device is running out of battery power and another task was performed to test the application while the mobile device is running out of memory space.

Table 3: Summary of Results for Data Downloading While Only One User is Connected to The LBS Server

Category	Size (Mbytes)	Time (Seconds)	Speed (KB/s)
Cat 1	0	0	0
Cat 2	2.29	26.66	85.90
Cat 3	3.88	44.09	88.00
Cat 4	5.93	66.33	89.40
Cat 5	7.36	87.62	84.00

Pilot Test: The first test was to check the functionality of the IRM application. During this test, the laptop was connected to the GPS receiver via a Bluetooth receiver. The main function of this stand-alone GPS receiver is to generate the NMEA string by receiving signals from the GPS available satellites [20]. The GPS receiver was connected to a Bluetooth serial port, which was in this example COM7. After a while, the IRM interface detected the NMEA string. The next step of this test was to check the available resources of the laptop. The location and the resources were gathered and displayed within an average of 1.46 ms time.

After displaying the resources, the end user chooses whether to proceed or to abort connecting and downloading data from the server. The next test scenario was to measure the time, speed and the size of data received according to different resource category and different number of users.

As can be seen in Table 3, this scenario was performed while only one user was connected to the server and the access point was set to provide a maximum speed of up to 1 Mbps, which means one user can theoretically get up to 128 KB/s. When the available device resources are in category 'Cat 1,' nothing should be downloaded simply because this category means that the mobile device is in critical situation for one of the following reasons:

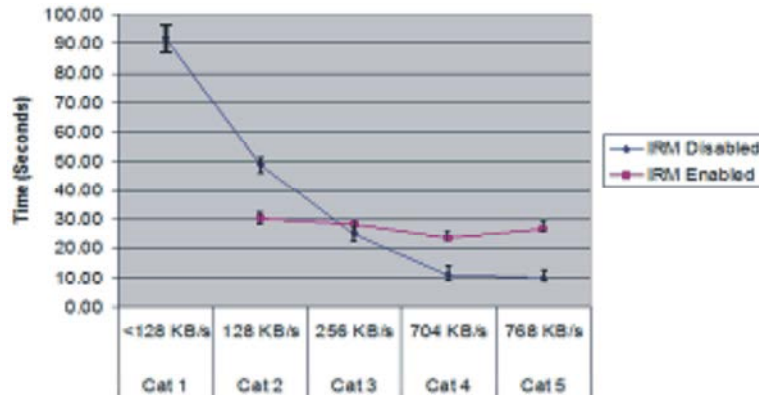


Fig. 9: Response Time Stability While Enabling/Disabling IRM Application

Table 4: Results of Data Downloading While Two Users are Connected to the LBS Server

Category	Size (Mbytes)	Time (Seconds)		Speed (KB/s)	
		User1	User2	User1	User2
Cat 1	0	0	0	0	0
Cat 2	2.29	46	51.33	49.78	44.61
Cat 3	3.88	79.67	84.33	48.70	46.01
Cat 4	5.93	123.67	127.67	47.95	46.45
Cat 5	7.36	158.33	163.67	46.49	44.97

- The available storage is less than a certain value (1 MBytes in this test),
- The battery power remaining is less than certain value (10% in this test),
- The network maximum speed is less than certain value (0.99 MBytes in this test).

When all of the aforementioned values raise each critical value, the application will be able to contact the server and download data. The results of this test, which can be seen in Table 3, have shown that when the category of the device is equal to 'Cat 2,' for example, a smaller size of data is downloaded. So in this case the size was 2.29 Mbytes, which is a map of 1 mile radius area without any videos or image supporting features.

However, when the category of the mobile device was 'Cat 5,' the size of downloaded data was larger (7.36 Mbytes), which is the total of a map of 2 miles radius supported with 1 image and 1 video.

Similar to the above test, another scenario was performed on two users at the same time. The aim of this test was to measure the time taken to download data while the wireless network is shared by users. In addition to the laptop used before, another one was utilised. This second laptop is a Dell® Windows Vista® operating system with Intel® Core™ 2 Duo Processor T5800 (2.0), supported with 2048 MB of DDR RAM.

The results of this test, which can be seen in Table 4, show that the connection speed was less than the one obtained from the previous test. In the previous test the average speed was 86.83 KB/s, whereas in this test it was 45.51 KB/s, which equals 52.4%. Therefore, sharing the network has increased the time to download data, for example in category 'Cat 1' the time taken to download data was 46 seconds for user1 and 51.33 seconds for user2, whereas it was 26.66 seconds in the previous test.

Data-flow Evaluation Test: The following evaluation was performed to test how IRM manages the flow of data according to the wireless connection speed. This test was completed in two steps, the first of which was downloading data from the LBS server while the IRM application was disabled and the second of which was downloading data while it was enabled.

- During the first task, the medium-size map (1.5 mile radius) was chosen as static-zone. The size of this map is exactly 3.88 Mbytes. This test was repeated 6 times and carried out on different connection speeds: 128 KB/s, 256 KB/s, 704 KB/s and 768 KB/s, which are supported by the D-Link® wireless access point. The results of this test show that downloading this map using a low connection speed takes longer and this time subsequently becomes lower and lower as the network speed increases. The blue line in Fig. 9 shows how the data downloading time is declining.
- In the second task, the IRM was enabled before starting the test process. This test scenario was repeated for the same four different connection speeds: 128 KB/s, 256 KB/s, 704 KB/s and 768 KB/s. When the speed was less than 128 KB/s, the application classified it in 'Cat 1,' which means that

no data should be transferred. Afterwards, when the speed was 128 KB/s (the lowest), the IRM application chose the minimum radius map, which is the 1 mile radius. The time taken to download the data was 30.51 seconds, which equals 62% of the time taken for the same case in the first task when the IRM was disabled.

At the second step, when the speed was 256 KB/s, IRM application chose the 1.5 mile radius map as the speed is located under 'Cat 3,' and the average time taken was around 28.12 seconds, which is approximately the result obtained from the same case in the previous scenario in the first task.

Next, when the speed was 704 KB/s, the IRM application chose the 2 mile radius map, as the speed is located under 'Cat 4,' and the average time taken was around 23.42 seconds, which is more than for the same scenario in the first task, but in this case the user received richer data, with about 38.9% extra information.

The last scenario was performed when the speed was 768 KB/s (the highest in this evaluation test). IRM classified this speed as 'Cat 5,' so the size of data was increased, unlike in the first task where the size of data was static. The time taken to download information related to this category was 26.75 seconds.

The outcome of this evaluation test has shown that the average downloading time scale using IRM is almost stable, whereas in the static mode, when the IRM application was disabled, the downloading time was dependent on the category of the network speed (Fig. 9). This result is very important according to [21]: stabilised response times will result in a usability enhancement, because users get annoyed or abandon a site if a service takes longer than expected.

To compare the difference between the two mechanisms statistically, a correlation test between the mobile status category and the downloading time for each case was conducted. This test is known as Pearson Product-Moment Correlation Coefficient (PMCC) [22]. The correlation results were calculated using Statistical Package for the Social Sciences (SPSS) [23].

During the first test, when IRM was disabled, there were five categories in the system ('Cat 1' to 'Cat 5'), then $n=5$. Hence, the degree of freedom $df=n-2$, which equals 3. The level of significance is considered as a common alpha $\alpha=0.05$.

The critical value in the table of PMCC was 0.88. This means that if the correlation r is less than -0.88, or greater than +0.88, then there is a significant relation between the two tested groups, otherwise there is no relation.

The result of the correlation test between the category and the response time was $r=-0.93$. This value is outside the boundaries (-0.88 and +0.88), thus it is concluded that there is a relation between the category of the mobile status and the response time.

In the second test, when IRM was enabled, there were 4 categories ('Cat 2' to 'Cat 5'), as no data is downloaded to the end user if his mobile has been classified as 'Cat 1'. In this case $n=4$ and the degree of freedom $df=2$. The critical value calculated from the table of PMCC was 0.95.

The result of the correlation test between the category and the response time was $r=-0.697$. As this value is within the range (greater than -0.95 and less than +0.95), it is concluded that there is no statistical relation between the category of the mobile status and the downloading time. Therefore, there is a difference between the two methods (IRM Disabled and IRM Enabled).

This significant difference proves that the size of data is changing slightly according to the connection speed. Therefore, IRM mechanism provides steady and intelligent service, which increases the efficiency of the wireless network and prevents any congestion. Consequently, IRM provides better quality services, which leads to an efficient LBS system.

Critical Situations Test: Another evaluation test was performed to investigate the benefits of IRM mechanism in critical situations compared to the currently available mechanisms. This test was conducted based on the previous test setup illustrated in Fig. 8 (above). The first scenario was to test downloading data while the client's device was running with poor battery power. The remaining power was only around 8% when the test began.

The first step was testing the IRM mechanism while the program 'BatteryInfo' was enabled. The result of this test was that the system refused to download any data because the power was less than 10%. In the second step, the program 'BatteryInfo' was disabled before starting the download process. The result of this test was that the application started downloading, but the mobile device went off before the download was complete.

The benefit of checking the battery power before contacting the server saves time, effort and money from a QoS point of view and saves the network bandwidth and the server time from a technical point of view. This would also improve the global energy saving which is one of the main purposes of this project.

In relation to the above test scenario, another test was conducted to evaluate the management of mobile device storage. IRM mechanism checks the size of the internal memory of the mobile device before retrieving data in order to save the device's memory as much as possible. Therefore, to test this feature, the hard drive of the laptop was overloaded with dummy data at the first step. The free space was only 1 Mbyte, which is less than the minimum storage required by IRM Application (2 Mbytes).

The first task of this trial was to test downloading data while the program 'StorageInfo' was enabled. The result of this test was that the system refused to download any data due to the lack of storage. In the second step, the program 'StorageInfo' was disabled before starting the download process. The result of this test was that the application displayed the map on the screen properly, but it was not cached on the hard drive. In this case, the operating system saved the map in the RAM to be used temporarily. Therefore, the end user is required to connect and download this data from the server every time as long as there is a lack of storage.

The outcome of this test has confirmed that the IRM mechanism is useful in saving time, effort and money, as well as the network bandwidth and the server time. This is because caching is very important for clients in order not to download the same piece of data every time. Moreover, this reduces the LBS server processing time, which results in providing service for more users at the same time.

CONCLUSION

In this paper, a dynamic Zone-based Update Mechanism for improving wireless LBS system performance and energy saving is presented and evaluated. A simplified prototype was implemented and evaluated using a mobile device. The results obtained from this work showed that this mechanism has significantly contributed to managing the size of information sent from the LBS server to the end user. Subsequently, the benefits of this new mechanism have been evaluated by comparing its functions with current systems. The results showed that the new mechanism has

minimised the time, effort and cost which might be added due to uploading redundant information or by losing data. The pilot test proved the efficiency of the developed mechanism in allocating the available bandwidth resources based on the mobile devices category and user requirement. The outcome of dataflow test showed that the average downloading time scale using IRM is almost stable during all trials, whereas it was varying in case the IRM was disabled. Additionally, the IRM was capable of managing data transmissions in critical situations, by continuously informing the application server with the available resources before and during the communication session. Accordingly, the IRM mechanism proves to be useful in managing the communication between the LBS user and the application server. Moreover, it has been proved that providing better QoS leads to energy saving as well as more green telecommunications for better life.

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