Research Article / Review Article

FUPRE JOURNAL 9(4):86-99(2025)
DOI: /10.60787/FJSIR.v9i4.86-99

FUPRE Journal

of

Scientific and Industrial Research

ISSN: 2579-1184(Print) ISSN: 2578-1129 (Online)

http://fupre.edu.ng/journal

# Development of FUPRE Analytical Radio Resource Management Template of General Packet Radio Service Applying Internet of Things Applications

***OTAVBORUO, E. E.*[1,*], *MASUD, A. A.*[2]**

[1,2]*Department of Electrical and Electronic Engineering, Federal University of Petroleum Resources, Effurun, Delta State*

**ARTICLE INFO**

*Received: 21/09/2025*
*Accepted: 11/11/2025*

**Keywords**

*Analytical, GPRS, IoT, Template.*

**ABSTRACT**

**This study utilized VBA six to developed an analytical radio resource management template for GPRS applying IoT application. It introduced the Static Partial Parallel Sharing Scheme (SPSS) and the Poisson Static Parallel Sharing Scheme (PPSS) analytics. Results collected were validated using the Pearson product moment correlation coefficient, and analyzed with the Turkey HSD, ANOVA, levene statistic and Bonferroni tools of statistical product for service solutions package. The result shows that the blocking probabilities (Pbs) of the PPSS, SPSS and SBSS increase from 2.83*10-13-1.0*10-6, 4.73*10-9-9.10*10-3 and 3.33*10-8-1, 19*10-1, respectively when the utilization factor is increased from 0.1 – 0.9, at specified value of the number of parallel queues (m = 1-7). The delay at m=3, 5 and ρ =0.1 - 0.9 are: 3.44*10-7 - 5.26*10-3, 1.60*10-8 - 2.46*10-4 seconds for the PPSS model; and 8.36*10-5 - 1.28, 5.10*10-5 - 077 seconds for the SPSS model, respectively. At m=1, and ρ = 0.1 - 0.9, the delay of the SBSS model ranges from 2.54*10-4 - 3.84 seconds. At ρ= 0.4 - 0.8 and m = 1 - 30, the expected variations in the queueing delay of each of the PPSS curves decrease with the following specified values: 1.06 - 1.19*10-9, 2.87 - 3.24*10-9, 6.35 - 7.38*10-9, 13.2 - 1.49*10-8, and 24.1 - 2.76*10-8 seconds, respectively. The decreases in the variations in the queueing delay of SPSS are: 1.06 - 34.2*10-2, 2.87 - 9.27*10-2, 6.35 - 2.11*10-2, 13.2 - 4.27*10-1, and 24.1 - 7.88*10-1 seconds, respectively.**

## 1. INTRODUCTION

General packet radio service (GPRS) supports multimedia services using both the Internet as well as the global system for mobile communication as interface. Whereas, the Internet supports packet switched services but not the circuit switching networks (Farshid and Victor, 2002, Xiaoyang, and Dipak, 2003). The GPRS transitions Internet connectivity from the traditional wired network of internet service provider or wired local area network to the revolutionary wireless Internet access. Simply said, the GPRS is a low cost, ubiquitous access to the wireless Internet as well as the forefront of the evolutionary data centric paradigm which points to the fourth generation (4G), fifth generation (5G) smart devices/networks. As a matter of fact, the GPRS system serves as the resources for which mobile subscribers communicate

*Corresponding author, e-mail: otavboruo.ericsson@fupre.edu.ng, abdulmujeebakajewole@gmail.com
DIO: DOI: /10.60787/FJSIR.v9i4.86-99
©Scientific Information, Documentation and Publishing Office at FUPRE Journal

packet data services over global system for mobile communication (GSM) radio channels (Baynat and Eisenmann, 2004). It has been observed by (Bima, *et al.*, 2020) that the Internet of things (IoT) could make use of the online data service of the low cost GPRS packet wireless services interface the GSM technology. Physical things are connected to the cloud server either through the gateway or internet protocol network backbone. Technologies such as the ZeeBig, Bluetooth, RFID, WLAN, WiMaX, GSM, GPRS narrowband IoT (No-IoT), long term evolution (LTE), LTE-advanced (LTE-A), etc. are examples of technologies utilized for Internet connectivity of things (Tang and Xie, 2021; Bima, *et al.*, 2020; Husain and Monet, 2017). When the LTE or the LTE-A is interfaced between a microcontroller and the cloud, IoT can be wirelessly linked via the microcontroller to the cellular LTE/LTE-A radio access and core networks, whereas the core network, made up of serving gateway and packet data gateway, is further connected to the cloud by a firewall (Huang, *et al.*, 2017). Thus GPRS being non-dedicated as well as cost saving cellular subsystem overlaid on the existing second-generation GSM system enhances scare wireless bandwidth and data revenue (Xiaoyang, and Dipak, 2003). It is classified into categories A, B and C. As class A system, GPRS system service both as circuit and packet switching simultaneously. When serving a class B GPRS system possesses the capability to switch the packets of users back and forth circuit and packet switching. Class C GPRS connects to one system at a time and it can be switched to the other when the need arises (Robert, 2002). It consumed network resource and bandwidth only when data is actually being transmitted (Jagadhesan, *et al.*, 2016). GPRS systems enhanced sharing of servers (channels) and buffers (storage facilities) thereby improving data network performance. Communication resources include. The capacity of channels and buffers resources could be defined as the maximum quantity of packets the GPRS server can transmit and the quantity that the buffer can accommodate temporally during traffic busy hours (Hamza, *et al.*, (2005). Optimum GPRS capacity is influenced by variables such as the traffic type, traffic intensity, service rate and arrival rate. GPRS buffer resource plays a critical role in handling real and non-real time traffics as both have opposing or contrasting quality of services (QoSs) (Chuah and Zhang, 2006). The 3GPP proposes separate bandwidths for transmitting voice and data packets. Data packet requesting GPRS connection are transmitted through the packet control unit (PCU) of the base station subsystem (BSS) and are further routed via the serving GPRS support node (SGSN), GPRS IP backbone network, and gateway GPRS support node (GGSN). Voice packets are transmitted from the BSS to the mobile switching station (MSC), home/visitors location registers (HLR/VLR), gateway mobile switching station (GMSC) to the packet switch telephone network (PSTN) or other voice networks. The main problem with the 3GPP architecture is that the voice resources could be available for use when the resources of the data path have been exhausted, and vice versa. Another problem inherent in the GPRS is the difficulty in allocating available resources accurately and optimally on demand. The implication is that resources are wasted in one of the channels while other channels are lacking to serving users requests. In developing countries, such as Nigeria, network providers increase the bandwidth as the mixed traffics increases. However, in Nigeria, excessive traffic from mixed sources continually congests the limited bandwidth which in return impede the GPRS performance (Otavboruo, *et al.* 2013). This is one of the major causes of the poor QoS experienced by the users. There is

therefore the need to first develop of an analytical radio resource template for the GPRS node, to restructure the modus of operation of the radio resource, and determine the extent of the improvement of the utilization/reservation of resources. This informed the desire to initiate the development of the graphical radio resource reservation templates for the Federal University of Petroleum Resources, Effurun (FUPRE). The templates display some of the characteristics of the GPRS QoSs parameters such as the blocking probability, queue delay and delay variation (jitter) of the GPRS node as influenced by the traffic pattern of users. Adequate statistical hypothesis which validates the template results, acceptance or rejection. Levene statistic and analysis of variance (ANOVA) of called statistical product for service solutions were used to compare the variance and averages of the schemes. Further pairwise comparison of the two schemes aligned very well with the Turkey HSD, Bonferroni, and Scheffe in terms of the significant difference in mean and equality of variance as portrayed Levene statistic and ANOVA. Two dynamic buffer resource management and buffer sharing analytical models proposed by Otavboruo (2014) applied to the GPRS resources template are the static_partial parallel sharing scheme (SPSS) and the Poisson_static parallel sharing scheme (PPSS). Both are compared to the single buffer sharing scheme. Both SPSS and PPSS are dynamic parallel buffers shared by parallel channels or servers. Detail explanation of how the sharing schemes operate are exploited in Otavboruo and Nzeako (2016).

## 2. REVIEW OF RELATED WORKS

A low cost IoT Based GPRS and Meteorological sensor system was designed in Nigeria by (Akintomide and Adedayo, 2024). The system consists BME 280, MQ5, UVM30A sensors connected to SIM 800L GSM/GPRS interface of ESP 32 microcontroller. The microcontroller reads data from the sensors and writes same to the WiFi. Consequently, the WiFi links the computing cloud which transfers the data to the GSS- MPD IoT platform for onward storage and processing. The research observed the designed system worked perfectly by measuring time series of pressure, relative humidity and ultraviolet index parameters. An article published by Habiyaremye, *et al.,* (2020) presents an Internet of Things application via the GSM/GPRSS sensor node in Rwanda. That particular research determines the mathematical model impacting the relationship between the effect of the received signal strength on the power consumed by the GPRS based sensor node and its lifetime in a specified location. Power consumed during data acquisition, and transmission was shown to be about 60% when GPRS has a maximum uplink data rate 85.6 kbps. Results of current consumed against the received signal strength indicator were presented at different location of GPRS. A comparative study between GPRS and Narrowband – Internet of Things (No-IoT) for transmission of data via the cloud situated in Bandung region, Indonesia was conducted by (Bima, *et al.*, 2020). That study took into consideration measurement of throughput, round trip time, and power consumption on a specified area of coverage by using computational analysis. In addition, the battery life and the packet loss of the two technologies were evaluated. A publication projected an embedded monitoring system which used the GPRS as the cellular link to transfer data to and fro the monitoring terminal and the ARM processor (Yang, 2017). A research study focused on developing an Internet of things automation which controls and monitor bulbs by applying the IoT paradigm with the aid of the

GPRS interfaced with cloud (Husain and Monnet, 2017). Sensors are connected to the SIM900 GPRS attached to the Ardiuno Uno board. The microcontroller periodically reads and sends the status of signals of the integrated sensors data via the cellular GPRS to the Internet server. Data were logged, saved, monitored and consulted during operations. The performance of the system was tested with the graphical interface HyperTerminal application which shows that the system responds to client requests for connection establishment. Qian (2023) developed a lithium battery monitoring system which consist of monitoring terminal, GPRS receiver and remote monitoring cloud platform. The GPRS was used to remotely monitor lithium batteries life in a wilderness environment in real time by using transmission error control method of retransmission to improve the reliability and availability of data transmission. No analysis was carried out on the design, it was only tested and it was concluded that it functioned properly. Investigation of two separate Markov transition state models for healthcare Internet of things applications, using biological sensors, was carried out in a study. All the sensors placed at different parts of the human body are interfaced wirelessly to the gateway using Bluetooth as well as ZigBee and the gateway, via a wireless fidelity/ a cellular is linked to the cloud. The cloud is further linked wirelessly to the healthcare provider network (Tang and Xie, 2021). Detailed numerical evaluation such as the probability of: (i) no service, (ii) full service, (iii) service degradation, and (iv) system availability was determined for varying connection failure rates. Data request through the cloud could also be connected via the SGSN, IP network backbone and GGSN to healthcare provider network as suggested in this research. Alternatively, cellular connection could be established via serving gateway and packet data gateway of the LTE network to get a better performance. Salameh *et al.* (2019) proposed a Markov model for four traffic classes with preemptive and non-preemptive priorities using the continuous time Markov chain for a single buffer and server. Analytical models were developed from which the average number of packets, blocking probability, average delay, overall pushout probability, performance to cost ratio, computed and plotted against class four arrival rate. All the technics deployed by the reviewed work addressed different parameters of QoS using available technological knowhow to connect physical things to the Internet while detecting signals from the sensors in a remote distance. To enhance those technics, this study designed a template which displays some QoS parameters graphically.

## 3. METHODOLOGY

Figure 3.1 illustrates the proposed physical model of the GPRS radio resource node in the basic service area where Internet of things applications signals are routed via the SGSN, IP network backbone and the GGSN to the service provider networks. The architecture is useful for computing the QoS parameters of the GPRS system. It consists of the sources, packet admitter, classifier and shaper, multiplexer, packet control unit (PCU), parallel transmission buffers linked to several channels by a packet dispatcher, and the buffer management scheme that controls the traffic load. Buffer management becomes imperative for data storage because congestion may render wireless telecommunication resources ineffective. It may cause unbalanced delay, throughput degradation and resource overload. Occasionally, it could lead to the blocking of packets in a wireless network (Daigle, 2005). Mixed packets, such as voice and data constitute the primary source of congestion. Thus, understanding: (i) the influence of overload on the resources; (ii) the switching

principles and the operational functions of the wireless links; and (iii) the buffer management scheme is essential for improving the QoS of a wireless network as shown in Kleinrock L. (1998) and Kleinrock (1996). The queue blocking probability, delay and delay variation of a group of buffers or servers are the three paramount key quality indicators (KQIs) when considering the buffer management scheme of congestion in a digital system. Researchers utilize both the STSs and the dynamic threshold schemes (DTSs) to manage packet requests in a buffer (Kleinrock 1998).

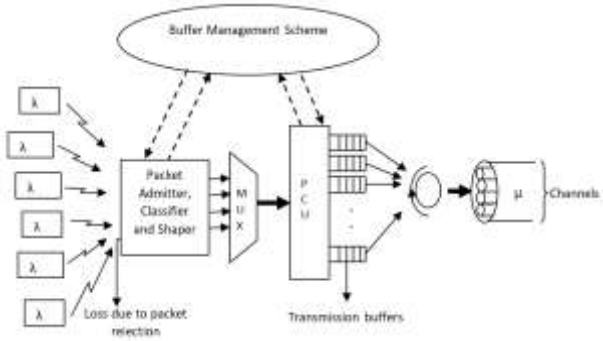



Figure 1: Proposed physical model of the general packet radio service

### 3.*1* *Development of GPRS and Radio Resource Templates using Visual Basic Six Application*

The term template has different meaning in usage. A web designer could describe the template as software and methodologies used to produce and deploy web pages on websites over the Internet (keir, 2013). Telecommunication template developed in this publication is an authenticity application software that is utilized in predicting the GPRS and other cellular traffic patterns. Template metaprogramming simply called template in the words of (Bancila, 2022) is a programming techniques that uses templates as blueprint for the compiler to generate codes and helps developer to avoid writing repetitive codes. Four types of templates commonly used in C++ programming are function, class, variable template and alias templates. The template developed herein are computationally numerical constants, graphical displays of telecommunication traffic applications, details of templates are inferred in Wei (2021). It, serve as an engineering template for reproducing traffic engineering models. This template possesses several graphical interfaces shown in Figures 2 , 3 to 4. Templates are visual types of project that can be created in Visual Basic – Windows form application, console application (Deitel, *et al.*, 2009). They are also used in the creation of several contents in websites and other applications (Keir, 2013). Visual basic application (VBA) six was used in the development of the analytical GPRS template. This application software: (i) automates tasks, (ii) interacts with central applications, (iii) imports and translate data, (iv) automates sequence of calculations and, (v) create custom form and specialized reports (Aspen, 2023).

The resource assignment template presented in Figure 2 is the developed template calculator used for computing the performance of the GPRS system that serves as the example radio resource implemented in this research. Figure 2 was developed with the visual basic (VBA) six application. Results obtained from the click events Figure 2 further produced the table and graphs in the template shown in Figure 4. The resource template calculator was developed using five inputs such as the arrival rate, service rate, number of channels, queue length and the number of queues and three outputs of the GPRS. Users enter real integers in the white spaces of the input interface and click the QoS command buttons of the SBSS, SPSS and PPSS schemes. The blocking probability, queue delay and queue delay variation of the schemes are computed based on the input parameters. The results of the computation are displayed as shown in Figure 4. When the

control buttons are clicked, they triggered the code statements of the SPSS, PPSS and SBSS analytical models which assign the resources and compute the QoS as well.

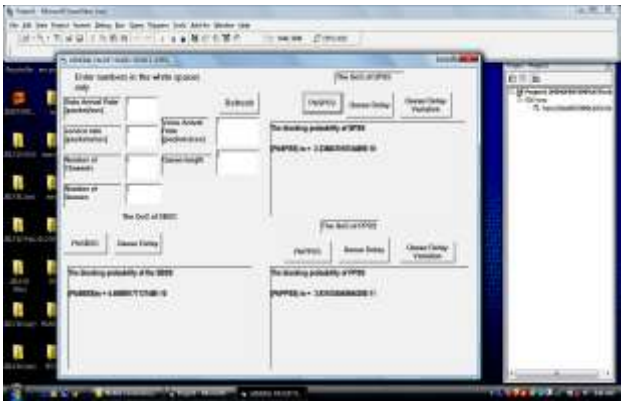


Figure 2: GPRS resource template calculator

This study also developed another template using the Microsoft Visual Basic 6 Application (VBA). Prior to the occurrence of traffic events, the template remains in the idle state a state when no traffic activities have occurred. This state is shown in Figure 3. Figure 3 was developed using thirteen command buttons and three picture boxes that have VBA codes running on their background. These codes were developed by opening the VBA application from the start icon of Microsoft Vista window. These VBA controls were inserted into the visual basic form from the toolbox on the left hand side of the figure. These controls also known as objects were added to the form by dragging and dropping or by double clicking the respective control icons. The sizes and locations of the controls in the form are specified with the properties window on the right hand side of the figure, and code statements were written for all of the controls (Aspen, 2023). These codes trigger events when the control buttons are clicked. An example of the template's blocking probabilities of the PPSS, SPSS and SBSS schemes are shown in Figure 3. The periphery of the form is known as the user interface of the template. A user interacts with the template by clicking the command buttons in order display the performance of the GPRS traffic patterns shown the Figure 4.



Figure 3: GPRS resource node Template in idle state

This particular research developed a GPRS templates which has the capability of reproducing the PPSS, SPSS, and SBSS performances of the traffic events of users' devices as depicted in Figure 4. The template provides a fast and an efficient way for capturing, visualizing and analyzing the traffic pattern of the GPRS system. Furthermore, the template displays the QoS parameters, such as the queue blocking probability, the queueing delay and the variation in the queueing delay. Radio engineers can employ it as a valuable tool for accessing the QoS of any wireless network. The significance of the resource template templates could be justified when it is applied to other wireless communication systems which include: (i) the GSM, (ii) wireless sensor network (WSN), (iii). UMTS, (iv) car racing systems, (v) database system, (vi) LTE network. Fifth generation is main target of the application of the template developed herein. Details of the Markov chain model and the analytical expressions have been shown in earlier works of the researchers in Otavboruo *et al.* (2014 and 2015). These will not be repeated here for want of space.

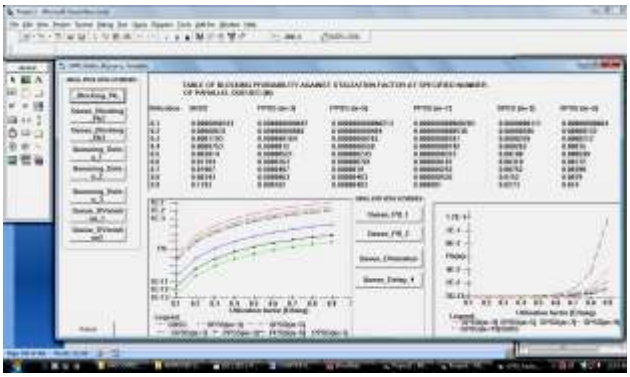


Figure 4: GPRS resource template graphical display of SPSS and PPSS traffic characteristics.

### *3.2 Model Verification of the PPSS and SPSS Schemes*

Results obtained is used to predict with a certain degree of accuracy the behaviour of the GPRS QoS traffic characteristic parameters. Prediction as used in this work implies determining the QoS of the PPSS and SPSS schemes. The schemes perform better than the other static sharing SBSS schemes as shown in Otavboruo (2014). The researcher of this study verified the connection, relationship or association among the PPSS, SPSS and SBSS schemes using of statistical correlation Otavboruo, *et al.*, 2014. Correlation is a statistical measurement often used to determine the relationship between two or more variables. One of the uses of the correlation coefficient is to determine whether or not a correlation exists between two population variables. It measures the significance and the type or the degree of strength of the relationship between the variables (Laura, 2019). There are different types of correlations. These include linear, curvilinear, biserial, partial and multiple correlation (Sahana, 2022). There are no hard and fast ways of interpreting the correlation strength. The guidelines given in the work presented by (Brase and Brase, 2018) regarding the correlation coefficient show that $0 < \tau_{xy} < 0.3$ is a weak correlation; $0.3 < \tau_{xy} < 0.7$ is a moderate correlation while $\tau_{xy} > 0.3$ indicates a strong correlation between x and y variables. Examples of statistical test used to determine the degree of correlations between sets of data include the Yule's Q; the Phi coefficient; the lambda (Guthman's coefficient or prediction); the Chi square; the Pearson's coefficient; the Spearman' rho; the Kendall's Tau; the Goodman and Kruskal's gamma; the Pearson r (product-moment correlation) coefficient. The Pearson product-moment correlation coefficient was used for verifying the PPSS and the SPSS schemes in this research. The expressions of the Pearson product-moment correlations are shown in Equations (1), (2), (3), and (4) (Fox and Sturdivant, 2023), (Sahana, 2022). Equation (4) is adopted for this study and it reveals that all the schemes are strongly related. The coefficient of Correlation ($\tau_{xy}$) of the blocking probability of SBSS and SPSS schemes 0.9852 whereas for the SBSS and PPSS $\tau_{xy}$ is 0.995, The value of $\tau_{xy}$ when variation in the queueing delay of the PPSS and SPSS and correlated with the SBSS schemes are 0.992 and 0.997 respectively. For the queueing delay the values of $\tau_{xy}$ for the PPSS and the SPSS in relation to SBSS are 0.9997 and 1 respectively. Result obtained from the Pearson product-moment show there is strong relationship between the models. The detail computation of the Pearson product-moment correlation coefficient is illustrated in Tables

$$\tau_{xy} = \frac{\sum (x_i - \bar{x})((y_i - \bar{y}))}{(n-1)S_x S_y} \quad (1)$$

$$\tau_{xy} = \frac{\sum x_i y_i - n\bar{x}\bar{y}}{(n-1)S_x S_y} \quad (2)$$

$$\tau_{xy} = \frac{\sum x_i y_i - \frac{\sum x_i \sum y_i}{n}}{\sqrt{\left(\sum x^2{}_i - \frac{(\sum x_i)^2}{n}\right) * \left(\sum y^2{}_i - \frac{(\sum y_i)^2}{n}\right)}} \quad (3)$$

$$\tau_{xy} = \frac{n\sum x_i y_i - \sum x_i \sum y_i}{\sqrt{n\sum x^2{}_i - (\sum x_i)^2}\sqrt{n\sum y^2{}_i - (\sum y_i)^2}} \quad (4)$$

Where,

$\bar{x}$ = sample mean of *x*

$\bar{y}$ = sample mean of $y$

$S_x$ = sample standard deviation of $x$

$S_y$ = sample standard deviation of $y$

Table1: Verification of the blocking probability of PPSS and SPSS with the SBSS

| | SBSS | PPSS @ m = 7 | SPSS @ m = 7 | | | | |
|---|---|---|---|---|---|---|---|
| $i$ | $x_i$ | $y_i$ | $y_{2i}$ | $x_i \times y_i$ | $x_i^2$ | $y_i^2$ | $x_i \times y_{2i}$ |
| 1 | 3.33E-08 | 2.83E-13 | 4.73E-09 | 9.44E-21 | 1.11E-15 | 8.03E-26 | 1.58E-16 |
| 2 | 6.31E-06 | 5.36E-11 | 8.68E-07 | 3.39E-16 | 3.99E-11 | 2.88E-21 | 5.48E-12 |
| 3 | 1.19E-4 | 1.01E-09 | 1.54E-05 | 1.21E-13 | 1.42E-08 | 1.03E-18 | 1.83E-09 |
| 4 | 8.75E-4 | 7.42E-09 | 1.03E-04 | 6.50E-12 | 7.66E-07 | 5.51E-17 | 9.02E-08 |
| 5 | 0.003814 | 3.23E-08 | 4.07E-04 | 1.23E-10 | 1.45E-05 | 1.04E-15 | 1.55E-06 |
| 6 | 0.012 | 1.01E-07 | 1.15E-03 | 1.21E-09 | 1.43E-04 | 1.02E-14 | 1.38E-05 |
| 7 | 0.03 | 2.52E-07 | 2.63E-03 | 7.53E-09 | 8.92E-04 | 6.36E-14 | 7.87E-05 |
| 8 | 0.06 | 5.35E-07 | 5.17E-03 | 3.39E-08 | 4.02E-03 | 2.86E-13 | 3.28E-04 |
| 9 | 0.12 | 1.00E-06 | 9.10E-03 | 1.20E-07 | 1.42E-02 | 1.01E-12 | 1.09E-03 |
| ∑ | 2.29E-01 | 1.93E-06 | 1.86E-02 | 1.63E-07 | 1.93E-02 | 1.37E-12 | 1.51E-03 |

$$\tau_{xy} = \frac{n\sum x_i y_i - \sum x_i \sum y_i}{\sqrt{n\sum x^2{}_i - \left(\sum x_i\right)}\sqrt{n\sum y^2{}_i - \left(\sum y_i\right)}} = 0.995$$

Coefficient of Correlation of the blocking probability of SBSS and SPSS schemes

$$\tau_{xy} = \frac{n\sum x_i y_{2i} - \sum x_i \sum y_{2i}}{\sqrt{n\sum x^2{}_i - \left(\sum x_i\right)}\sqrt{n\sum y^2{}_{2i} - \left(\sum y_{2i}\right)}} = 0.9852$$

Table 2: Verification Queue delay variation of PPSS and SPSS with SBSS

| | SBSS | PPSS @ m = 6 | SPSS @ m = 6 | | | | | |
|---|---|---|---|---|---|---|---|---|
| $i$ | $x_i$ | $y_i$ | $y_{2i}$ | $x_i \times y_i$ | $x_i^2$ | $y_i^2$ | $x_i \times y_{2i}$ | $y_{2i}^2$ |
| 1 | 2.84E-03 | 7.82E-12 | 4.73E-04 | 2.22E-14 | 8.07E-06 | 6.12E-2 | 1.34E-06 | 2.24E-0 |
| 2 | 5.74E-02 | 1.58E-10 | 9.57E-03 | 9.07E-12 | 3.29E-03 | 2.50E-2 | 5.49E-04 | 9.16E-0 |
| 3 | 3.79E-01 | 1.05E-09 | 6.32E-02 | 3.98E-10 | 1.44E-01 | 1.10E-1 | 2.40E-02 | 3.99E-0 |
| 4 | 1.62E+00 | 4.47E-09 | 2.70E-01 | 7.24E-09 | 2.62E+00 | 2.00E-1 | 4.37E-01 | 7.29E-0 |
| 5 | 5.53E+00 | 1.53E-08 | 9.13E-01 | 8.46E-08 | 3.06E+01 | 2.34E-1 | 5.05E+00 | 8.34E-0 |
| 6 | 1.65E+01 | 4.58E-08 | 2.77E+00 | 7.56E-07 | 2.72E+02 | 2.10E-1 | 4.57E+01 | 7.67E+0 |
| 7 | 4.48E+01 | 1.26E-07 | 7.58E+00 | 5.64E-06 | 2.01E+03 | 1.59E-1 | 3.40E+02 | 5.75E+0 |
| 8 | 1.11E+02 | 3.22E-07 | 1.92E+01 | 3.57E-05 | 1.23E+04 | 1.04E-1 | 2.13E+03 | 3.69E+0 |
| 9 | 2.49E+02 | 7.77E-07 | 4.61E+01 | 1.93E-04 | 6.20E+04 | 6.04E-1 | 1.15E+04 | 2.13E+0 |
| ∑ | 4.29E+02 | 1.29E-06 | 7.69E+01 | 2.36E-04 | 7.66E+04 | 7.26E-1 | 1.40E+04 | 2.56E+0 |

The coefficient of correlation of the Pearson of the queue delay variation of the PPSS and the SBSS schemes

$$\tau_{xy} = \frac{n\sum x_i y_i - \sum x_i \sum y_i}{\sqrt{n\sum x^2{}_i - \left(\sum x_i\right)}\sqrt{n\sum y^2{}_i - \left(\sum y_i\right)}} = 0.9992$$

The coefficient of correlation of the Pearson of the queue delay variation of the PPSS and the SBSS schemes

$$\tau_{xy} = \frac{n\sum x_i y_{2i} - \sum x_i \sum y_{2i}}{\sqrt{n\sum x^2{}_i - \left(\sum x_i\right)}\sqrt{n\sum y^2{}_{2i} - \left(\sum y_{2i}\right)}} = 0.9993$$

Table 3: Verification of PPSS and SPSS with SBSS of Queue delay

| | SBSS | PPSS m=5 | SPSS m=5 | | | | |
|---|---|---|---|---|---|---|---|
| $i$ | $x_i$ | $y_i$ | $y_{2i}$ | $x_i \times y_i$ | $x_i^2$ | $y_i^2$ | $x_i \times y_{2i}$ | $y_{2i}^2$ |
| 1 | 2.51E-04 | 1.60E-08 | 5.10E-05 | 4.02E-12 | 6.30E-08 | 2.56E-16 | 1.28E-08 | 2.60E-09 |
| 2 | 4.68E-03 | 2.99E-07 | 9.36E-04 | 1.40E-09 | 2.19E-05 | 8.94E-14 | 4.38E-06 | 8.76E-07 |
| 3 | 2.71E-02 | 1.73E-06 | 5.41E-03 | 4.69E-08 | 7.34E-04 | 2.99E-12 | 1.47E-04 | 2.93E-05 |
| 4 | 9.63E-02 | 6.16E-06 | 1.93E-02 | 5.93E-07 | 9.27E-03 | 3.79E-11 | 1.86E-03 | 3.72E-04 |
| 5 | 2.61E-01 | 1.67E-05 | 5.22E-02 | 4.36E-06 | 6.81E-02 | 2.79E-10 | 1.36E-02 | 2.72E-03 |
| 6 | 5.96E-01 | 3.81E-05 | 1.19E-01 | 2.27E-05 | 3.55E-01 | 1.45E-09 | 7.09E-02 | 1.42E-02 |
| 7 | 1.20E+00 | 7.70E-05 | 2.41E-01 | 9.24E-05 | 1.44E+00 | 5.93E-09 | 2.89E-01 | 5.81E-02 |
| 8 | 2.20E+00 | 1.42E-04 | 4.45E-01 | 3.12E-04 | 4.84E+00 | 2.02E-08 | 9.79E-01 | 1.98E-01 |
| 9 | 3.84E+00 | 2.46E-04 | 7.68E-01 | 9.45E-04 | 1.47E+01 | 6.05E-08 | 2.95E+00 | 5.90E-01 |
| ∑ | 8.23E+00 | 5.28E-04 | 1.65E+00 | 1.38E-03 | 2.15E+01 | 8.84E-08 | 4.30E+00 | 8.63E-01 |

The coefficient of correlation of the of the buffer queue delay of PPSS and SBSS schemes

$$\tau_{xy} = \frac{n\sum x_i y_i - \sum x_i \sum y_i}{\sqrt{n\sum x^2{}_i - \left(\sum x_i\right)}\sqrt{n\sum y^2{}_i - \left(\sum y_i\right)}} = 0.9997$$

The coefficient of correlation of the of the buffer queue delay of SPSS and SBSS schemes

$$\tau_{xy} = \frac{n\sum x_i y_{2i} - \sum x_i \sum y_{2i}}{\sqrt{n\sum x^2{}_i - \left(\sum x_i\right)}\sqrt{n\sum y^2{}_{2i} - \left(\sum y_{2i}\right)}} = 1$$

## 4. RESULT PRESENTATION AND DISCUSSION

The results of the models were presented in the resource template after which the QoS and the statistical analysis of the node are carried out. Statistical analysis determines whether there is any significant difference or not between the PPSS/SPSS and the existing SBSS at the 95 % level of confidence. Levene statistic and analysis of variance (ANOVA) were used to compare the variance and averages of the schemes by using the software called statistical product for service solutions previously known as statistical package for social science. These determined equality of the variance as well as averages (mean of the three schemes) at 5% error (0.05) or 95% level of confidence. This leads to the

question: Is there any significant difference in the mathematical models simulated in this works? To answer this question, the null and alternative hypotheses of the mathematical models were tested. The null hypothesis states (Ho) that there is no significant difference between the schemes, while the alternative hypothesis (Ha) states that there is a significant difference.

**Hypotheses**

Ho: $\mu_1 = \mu_2 = \mu_3$,

Ha: $\mu_1 \neq \mu_2 \neq \mu_3$,

Where,

Ho = Null hypothesis; the averages of the schemes are equal,

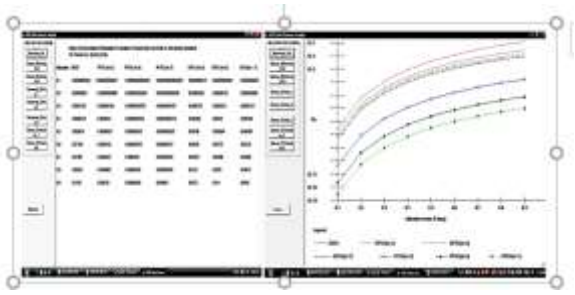
Ha = alternative hypothesis; the averages of the schemes are not equal,

$\mu_1$ = mean of the blocking probability of the SBSS scheme at specified m,

$\mu_2$ = mean of the blocking probability of the PPSS scheme at specified m,

$\mu_3$ = the mean of the blocking probability of SPSS scheme.

The result of the blocking probability of the PPSS, SPSS and SBSS schemes presented in the table and graphical display Figure 1. shows that the blocking probability of all the schemes increases exponentially with the linear increase in the utilization factor (UF). The SBSS scheme has the highest blocking probability while PPSS has the smallest blocking probability as depicted in Figure 1.The Pbs of the PPSS, SPSS and SBSS increased from $2.83\times10^{-13}$to $1.0\times10^{-6}$, $4.73\times10^{-9}$ to $9.10\times10^{-3}$ and $3.33\times10^{-8}$ to 1, $19\times10^{-1}$, respectively. The average of the blocking probability of the schemes shows that the averages are different. However, there is no significant difference in the averages of the schemes as revealed ANOVA (p = 0.437). The test of homogeneity of variance reveals the variance of the schemes is lesser than 0.05 ($p < 0.05$). The p-value supports the alternative hypothesis and the non-equality of variance as well.



m = number of parallel queues Pb = queue blocking probability

**Figure 1:** Queue Blocking Probability of PPSS, SPSS and SBSS against utilization factor at specified number of parallel queues

The slow increase in the Pbs of the PPSS and the SPSS scheme with the changed in the utilization factor of the node, at specified queue capacity (k), is described in Figure 2. The Pbs increase exponentially with the linear increased in the utilization factor at k = 5, 10, 15 packet capacities correspondingly. The Pbs of the PPSS scheme changed from 1.00×10-31 to 6.39×10-16, 1.69×10-22 to 2.22×10-11 and 2.83×10-13 to 1.00×10-6, respectively, for the range of k specified. The corresponding Pbs of the SPSS scheme changed from 6.64×10-9 to 1.40×10-2, 4.73 ×10-14 to 1.36x10-3, and 4.73×10-19 to 1.36×10-3, at k = 5, 10, 15 packet capacities. The statistical product for service solutions software environment does not display the value of the mean when it is greater than four decimal places, but significant equality value of the equality of variance is lesser than 0.05 or 5%. The significant difference of the mean and variance of the PPSS and SPSS schemes supported the alternative hypothesis of non-equality of mean and variance. Further pairwise comparison of the two schemes using Turkey HSD, Bonferroni, Scheffe, aligned with the significant difference in mean and equality of variance of Levene

statistic.

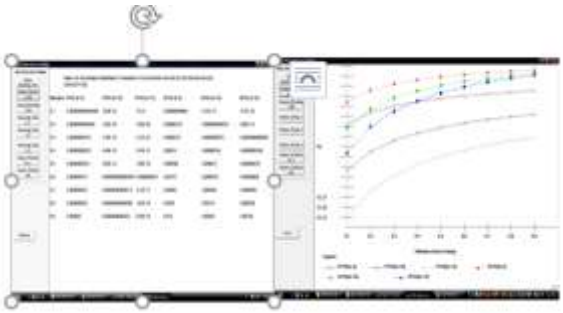
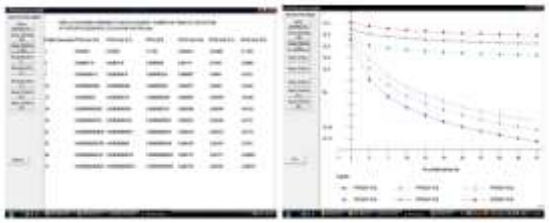


**Figure 2:** Queue blocking probability of the PPSS and SPSS against utilization factor (UF) at specified queue capacities of k = 5, 10, 15

The inverse relationship between the Pbs and the amount parallel queue of the PPSS/SPSS schemes is presented in Figure 3. The PPSS scheme rejected the smallest number of packets (UF = 0.5) while the SPSS scheme rejected the highest number of packets (UF= 0.9). The values of $P_b$ in the PPSS decrease exponentially from $3.81\times10^{-3}$ to $5.46\times10^{-12}$; $2.99\times10^{-2}$ to $5.11\times10^{-11}$; 0.12 to $2.97\times10^{-7}$, whereas the Pbs in the SPSS schemes decrease from $3.81\times10^{-3}$ to $1.55\times10^{-4}$; $2.99\times10^{-2}$ to $1.55\times10^{-3}$ and 0.12 to $8.19\times10^{-3}$ as the number of parallel queues is increased from 1 to 31, correspondingly. The mean of the schemes is less than 0.05 The test of homogeneity of variance of the schemes are significantly different for the of PPSS and SPSS against the number of parallel queues at specified utilization factors.



rho = utilization factor (UF), Pb = Queue blocking probability

**Figure 3:** Queue Blocking probability (Pb) of PPSS and SPSS against the number of parallel queues at specified resource utilization factors

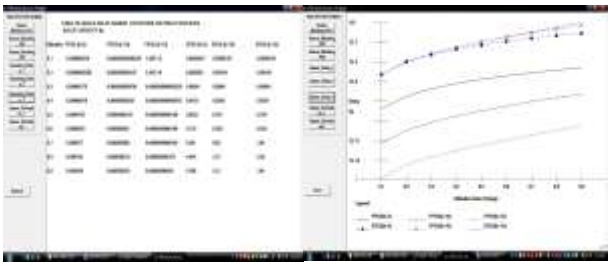
At m = 3 and 5, the queue delay increased from $3\times10^{-7}$ to $5.26\times10^{-3}$ and $1.60\times10^{-8}$ to $2.46\times10^{-4}$ seconds for the PPSS model; while the queue delay is increased $8.36\times10^{-5}$ to 1.28 and $5.10\times10^{-5}$ to 077 seconds for the SPSS model, respectively. At m=1, and UF = 0.1 to 0.9, the delay of the SBSS scheme changed from $2.54\times10^{-4}$ to 3.84 seconds as depicted in Figure 4. At m=1, when the UF is increased from 0.1 to 0.9, the delay of the SBSS scheme changed from $2.54\times10^{-4}$ to 3.84 seconds. The mean, ANOVA and test of homogeneity or equality of variance of queue delay of SBSS, PPSS and SBSS schemes against utilization showed that there are significant differences between the respective averages, and the variance of the SBSS, SPSS and PPSS schemes, hence the rejection of the null hypothesis.



m = number of parallel queues, rho = utilization factor (UF)

**Figure 4:** Queue delay of PPSS, SPSS and SBSS vs utilization factor at specified number of parallel queues

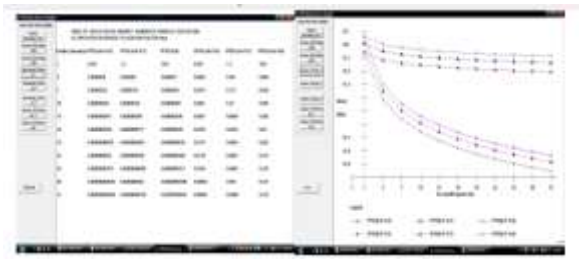
The individual delay of the PPSS and SPSS schemes against the UF at specified values k is illustrated in Figure 5. It was observed that the measured value of the delay caused by the PPSS is lower than the delay of the SPSS scheme. The delays of both schemes are improved when k is small. However, the delay of the models increases with an increase in the UF. In the figure, the delay of the SPSS tends to converge when the utilization factor increase from 0.1 to 0.3 Erlang and diverges from 0.4 to 0.9 Erlang. The p value in the ANOVA supported the null hypothesis, whereas the test of equality or homogeneity revealed that the variance of the queue delay is significant, that is $p < 0.05$.



k = queue capacity, delay = queue delay

**Figure 5:** Queue delay of PPSS and SPSS vs. Utilization factor (UF) at specified queue capacities

Figure 6 showed that when the number of the parallel queues(m) is changed from 1 to 31, at specified values of UF = 0.9, 0.7, 0.5, the queue delay of the SPSS scheme decreases from 3.84 to $1.24\times10^{-1}$; 1.2 to $3.88\times10^{-2}$, $1.2\times10^{-1}$ to $8.42\times10^{-3}$, respectively. The corresponding queue delays of the PPSS decreased from: 3.84 to $4.32\times10^{-9}$; 1.2 to $1.36\times10^{-9}$; and $1.2\times10^{-1}$ to $2.94\times10^{-10}$ for the same range of UF specified above. Despite the significance of the homogeneity of variance of the schemes, the averages of the schemes showed that null hypothesis is accepted which may likely not be as suggested in this the case.



rho = UF = utilization factor

**Figure 6:** Queue delay of PPSS and SPSS vs. Number of parallel queues (m) at specified Utilization factors (UFs).

Figure 7 showed that for a single queue (m = 1), the performances are the same of the queue delay variation of the PPSS, the SPSS, and the SBSS schemes are identical. The delay variations of the PPSS when the following parameters c=3, k=10, n=13, $P_0 = 0.23211$, and m = 6 to 12, are: $7.82\times10^{-12}$ to $7.77\times10^{7}$, $3.3\times10^{-13}$ to $3.28\times10^{-8}$, $2.84\times10^{-14}$ to $2.82\times10^{-9}$, $3.82\times10^{-15}$ to $3.79\times10^{-10}$ seconds, using the same constant parameters for the SPSS the delay variations changed from $4.73\times10^{-4}$ to $4.61\times10^{1}$, $3.55\times10^{-4}$ to $47\times10^{1}$, $2.84\times10^{-4}$ to $2.78\times10^{1}$, $2.36\times10^{-4}$ to $2.33\times10^{1}$ seconds, respectively.

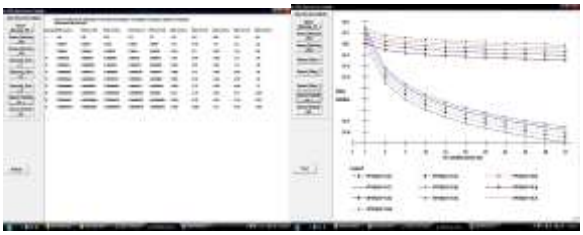
Statistical analysis showed that the SBSS delay variation is higher than the PPSS and SPSS respectively. Thus, there is a significant difference in the queue delay variation of the schemes.



rho = utilization factor, m = number of parallel queues

**Figure 7:** Queue delay variation of PPSS, SPSS and SBSS against Utilization Factor (UF) at specified number of parallel queues

Figure 8 showed that the variations in the queue delay of the PPSS and the SPSS decrease with the increase in the number of parallel queues at specified UF. The delay variations of the PPSS decreased steeply whereas for the SPSS scheme deceased gradually with the increase in UF. At values of UFs ranging from 0.4 to 0.8 and m from 1 to 30 packets, the expected delay variations of each of the PPSS curves decrease from: 1.06 to $1.19\times10^{-9}$, 2.87 to $3.24\times10^{-9}$, 6.35 to $7.38\times10^{-9}$, 13.2 to $1.49\times10^{-8}$, and 24.1 to $2.76\times10^{-8}$ seconds, respectively. The delay variations of the SPSS curves in the figure changes from: 1.06 to $34.2\times10^{-2}$, 2.87 to $9.27\times10^{-2}$, 6.35 to $2.11\times10^{-2}$, 13.2 to $4.27\times10^{-1}$, and 24.1 to $7.88\times10^{-1}$ seconds, respectively. Statistical analysis showed that there is no significant difference in the mean of the queue delay variation between the PPSS and the SPSS scheme However, there is a significant difference in the variance between the schemes.



rho = UF = utilization

**Figure 8:** Queue delay variation of PPSS and SPSS against number of parallel queues at specified UFs

## 5. CONCLUSION

The study developed the FUPRE analytical radio resource management template of GPRS applying the IoT. The template was validate using Pearson product moment of coefficient of correlation, while statistical product for service solution was used to carry out statistical analysis. It was observed that the blocking probability, queue delay and queue delay variation of the PPSS, SPSS and SBSS increased with the increase in utilization and decrease with the increase in the number of parallel queue.

**Acknowledgement**

I give thanks to God who has made this research a reality. I also acknowledge the Department of Electrical and Electronics Engineering as well COET and FUPRE for giving me the platform to realizing the research.

## References

Akintomide, O., Adedayo, K. D. (2024). Development of an IoT-Based GSM Signal Strength and Meteorological Parameters Monitoring Devices, *Iconic Research and Engineering Journal*, vol. 7, iss. 11, 520 – 528.

Aspen, O. (2023). Visual Basic Quick Start Guide, Packt, Birmingham.

Avi-Itzhak, B., Maxwell, W. L and Miller L. W, "Queueing with Alternating Priorities," *Opns. Res.*, vol. 13, no. 2, Mar. -Apr., 1965306-318.

Bancila, M. (2022) Template Metaprogramming with C++. Packt, Birmingham, 1- 17.

Baynat, B., and Eisenmann, P. (2004). Towards an Erlang-Like Law for GPRS/EDGE Network Engineering, Proc. *IEEE Conf. on International Conference on Communication (ICC)*, Paris, 3689-3695. Robert L. (2002). QoS in Integrated 3G Networks, Boston, Artech House Inc.

Bima, W., *et al.* (2020). A performance Analysis of General Packet Radio Service (GPRS) and Narrowband Internet of Things (NB-IoT) in Indonesia, Kinetik: Game Technology, Information System, Computer Network, Computing, Electronics, and Control, 5(1). doi:https://doi.org/10.22219/kinetik.v5i1.947.

Brase, C. H., Brase, C. P. (2018). Understandable Statistic: Concepts and Methods, Cage learning, Boston.

Chuah, M. C. and Zhang, Q. (2006). Design and Performance of 3G Wireless Networks and Wireless LANs, New York, Springer.

Daigle, J. N. (2005). Queueing Theory with Applications to Packet Telecommunication, Springer, Boston.

Deitel, P. J., Deitel, H. M., Ayer, G.J. (2009). Simply Visual Basic 2008, Pearson Prentice Hall, New Jersey, 60.

Farshid, A., Victor, C. M. L. (2002). QoS Support in the UMTS/GPRS Backbone Network Using DiffServ, *Proc. IEEE Conf. on GLOBCOM*, Taipei, Taiwan, pp. 1449-14453.

Fox, P. W., Sturdivant, R. X. (2023). Probability and Statistics for Engineering and the Sciences with Modeling using R, CRC Press, 273 – 275.

Habiyaremye, J., *et al*.. (2020). GPRS Sensor

Node Battery Life Span Prediction Based on Received Signal Strength Quality: Experimental Study, *Information*, 1 – 21.

Hamza, D., *et al.* (2005). Performance Modelling of GSM/GPRS Cells with Different Radio Resource Allocation Strategies, *Proc. IEEE Conf. on WCNC*, New Orleans, LA, 1317-1322.

Huang, J., *et al.* (2013). An In-depth Study of LTE: Effect of Network Protocol and Application Behavior on Performance, *IEEE SIGCOM*, Hong Kong, 13, 365.

Husain, B. M., Monnet W. M. (2017). An Internet of Things Application Through GPRS, *International Engineering Conference on Developments in Civil and Computer Engineering Application*, 153 – 162. https://www.researchgate.net/publication/323546103

Jegadhesan, B., *et al.* (2016). An Optimization Concept for Capacity Analysis of (3G – 4G) in Relation to vQuality of Service, *International Journal of Computer Science and Information Technology Research*, vol. 4, 3, 274.

Keir, B. (2013). Visualforce Development Cookbook, Packt, Birmingham.

Kleinrock, L. (1967). Time-Shared System: A Theoretical System, *Journal of the ACM*, 14(2), 242 - 261.

Kleinrock, L. (1998). Performance Evaluation of Distributed Computer-Communication System, Computer Science Department, University of California, Los Angeles, 1-81.

Knessl, C. *et al.* (2002-2003). A Dynamic Queue Model for Simultaneous Service of Two Traffic Types, *SIAM*, vol. 63, no. 2, 398-422.

Laura, M. C. (2019). Mathematical Statistics with Resampling and R, Wiley, 301-304.

Otavboruo, E. E. *et al.* (2013). Implementation of Static Threshold Schemes in a GPRS Radio Resource Template, *International Journal of Electronics and Communication Engineering (IJECE)*, Vol. 2, I ssue 1, February, 105-114.

Otavboruo, E. E. *et al.* (2014). Radio Resource Allocation: Evaluation of PPSS, SPSS and SBSS Schemes, *International Journal of Electronics and Communication Engineering (IJECE)*, Vol. 3, Issue 5, 27-40.

Otavboruo, E. E., Nzeako A. N. (2015). Development of an Analytical GPRS Resource Management Template for General Packet Radio Service, Ph.D. Thesis, Department of Electronic Engineering, Faculty of Engineering, University of Nigeria, Nsukka, 1 – 275.

Sahana, P. (2022). Elementary Statistical Methods, Springer, Bangalore, 241 – 279.

Salameh,O., *et al.* (2019). A Markovian Model for Internet of Things Application, *International Journal of Computer Networks and Communications (IJCNC)*, vol. 2, no. 2, 113 – 124.

Tang, S., Xie Y. (2021). Availability modelling and Performance Improving of a Healthcare Internet of Things (IoT) System, *MDPI IoT*, 2, 310 -325. https://www.mdpi.com/journals/iot.

Wei, L. (2021). C++ Template Metaprogramming in Practice: A Deep Learning Framework, CRC Press, New York, 46 – 52.

Xiaoyang, F., and Dipak G. (2003). Performance Modeling and QoS Evaluation of MAC/RLC Layer in GSM/GPRS Networks, Proc. *38th IEEE Conf. on International*

*Conference on Communication (ICC)*, Anchorage, Alaska, 271-275.

Yaipairoj, S. (2004). Performance Analysis of GSM/GPRS System with Channel Impairment, *IEEE WCNC*, 2514-2518.

Yang,Y. (2017). Design of Wireless Monitoring System Based on GPRS, *2nd Join International Information, Mechanical and Electronic Conference*, vol. 62, pp. 585 – 588.

Zang, R., Qian F. (2023). Design of Lithium Battery Monitoring System Based on GPRS Short Message Communication, E3S Web of Conferences, 1 - 4. https://doi.org/10.1051/e3sconf/202340602044