Research Journal of Applied Sciences, Engineering and Technology 4(11): 1432-1437, 2012
ISSN: 2040-7467

Submitted: March 19, 2011 Accepted: May10, 2011 Published: June 01, 2012

Determination of Traffic Load and Traffic Performance Parameters in Mobile Communication in Nigeria

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Abstract: The study presents a determination of traffic load and traffic performance parameters (indicators) in mobile communication network, using Nigeria (Lagos) as a case study. The operation and maintenance unit which is in-built with the mobile communication network was used as a measuring device. The traffic data obtained from the mobile network are; number of complete call, number of calls attempts and service time (calls duration) for the period of one year. These traffic parameters was used to determine the offered traffic, block traffic (loss traffic) and other traffic performance parameters also called Traffic Key Performance Indicator (KPI). They are Calls Completion Rate (CCR), Busy Hour Call Attempt (BHCA), Grade of Service (GOS) and Channels Utilization Percentage (CUP). It was discovered that route 9 and 10 Call Completion Rate (CCR) was not in accordance with Nigeria Communication Commission (NCC, 2008) regulation. The Grade of Service (GOS) of route 7, 8, 9, 10, 11, 12, 13 and 18 are not in accordance with NCC regulation. Also, the channel utilization percentage is above 60% stated by NCC. These will result in loss of calls or block calls in affected routes. Effort should be made by operators to provide good quality of service (QOS) and monitoring agency (NCC) should ensure that they conform to recommended standard to avoid block calls during the busy hour.

Key words: Arrival rate, service time, stochastic process, traffic intensity, traffic performance parameters

INTRODUCTION

Traffic in mobile communication is referred to as either the amount of data or voice calls or both, over a circuit (channels) during a given period of time. Traffic unit is a measure of traffic intensity. The international unit of traffic intensity is the Erlang. It represents the proportion of time an hour that a circuit is occupied.

$$\begin{aligned} 1 \text{ Erlang} &= 1\text{call} - \text{hour} = 3600 \text{ call - second} \\ &= 36 \text{ ccs -} \end{aligned} \tag{1}$$

CCS = Calls Centrum Seconds or call hundred seconds. The general view of mobile communication traffic path is shown in Fig. 1 while the Mobile Station (MS) is situated inside a cell site coverage region.

The air-interface links the mobile station to the Base Tranreceiver Station (BTS). The GSM 900: 45MHz, have both uplink and downlink (Fig. 2).

The transmission over the air-interface is digital signal. Digital transmission in GSM is both FDMA and TDMA. The FDMA subdivide the 25 MHz into 124 channels of 200 KHz, while the TDMA subdivide each 124 channels into 8 timeslots; making a total of 992 channels.

A simple TDMA frame consists of eight physical channels, or timeslots. A timeslot is 0.577 ($^{15}/_{26}$ms) duration with 156.25 bit rate per timeslot, eight timeslots or frame is ($^{120}/_{26}$ms) 4.615 ms (8 × 0.577ms) and total bit rate is 271 kbps per TDMA frame. The information transmitter in the TDMA frame is called a burst (Juha, 2003).

Types of burst are normal burst, frequency correction burst, synchronization burst, dummy burst, access burst.

The TDMA frame are grouped into two types of multiframes. They are:

- 26-frame multiframe (4.615 ms × 26 = 120 ms) comprising of 26 TDMA frame. This multiframe is used to carry traffic channels and their associated control channel.
- 51-frame multiframe (4.615mms × 51 = 235.4 ms) comprising 51 TDMA frame. This multiframe is exclusively used for control channels.

These multiframe structure is further multiplexed into a single superframe and hyperframe (Regis, 2002).

Several logical channels are mapped onto the physical channels. The logical channel is subdivided into various types of channels as shown in Fig. 3.

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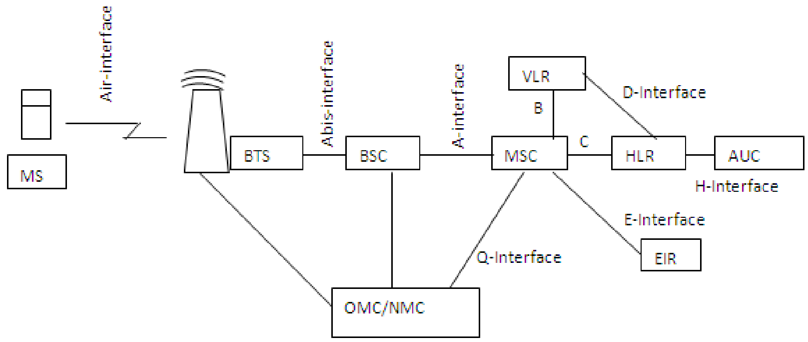

Fig. 1: Architecture of traffic path between the mobile communication elements or nodes

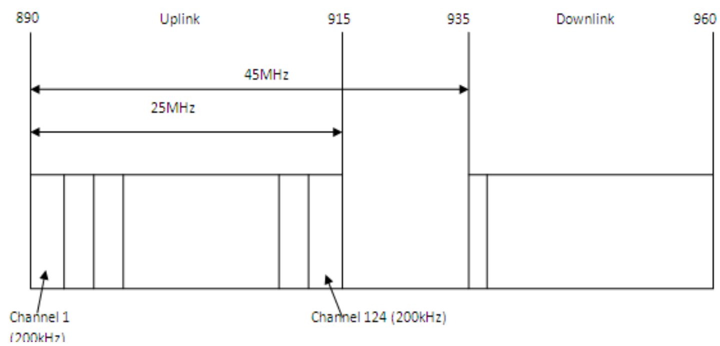

Fig. 2: Bandwidth fragmentation

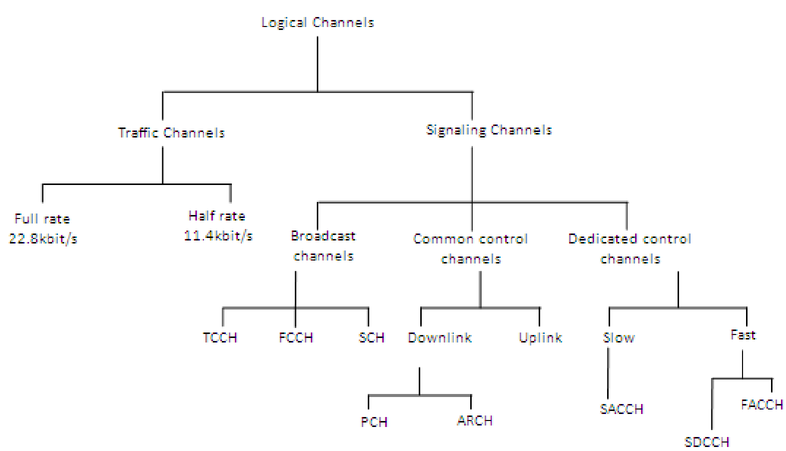

Fig. 3: Logical Channels

The half-rate Traffic Channel (TCH) doubles the capacity of a system effectively by making it possible to transmit two calls in a single channels (Juha, 2003).

The Abis-interface lies within the Base Transreceiver Station (BTS) and the Base Station Controller (BSC) can be connected using leased lines, radio link or Metropolitan Area Networks (MANs). The transmission rate of the Abis interface is 2048kbps, which is partitioned into thirty-two 64kpbs sub-channels. Basically, two channel types exist between the BSC and BTS. They are:

- Traffic Channels (TCH): Which can be configured into 8, 16 and 64 kbit/s formats and transport user data
- Signaling channels can be configured into 16, 32, 56 and 64 kbit/s formats and are used for signaling purpose between the BTS and BSC

Channel 0 is used for synchronization; the remaining 31 channels transmit warning information for operation and maintenance of the BTS, known as O and M alarms as well as signaling and voice data.

The A-interface lies between the Base Station Controller (BSC) and mobile switching center (Gunner, 1998).

A-ter interface and A-interface: The A-ter interface connects the transcoder with the Base Station Controller (BSC), while the A-interface connects the Mobile Service Switching Center (MSC) with the Transcoder (TC). The A-interface is an ISDN-S2M interface that has been adjusted to GSM with a data rate of 64kbps per timeslot. In the PCM 30 configuration, the A-interface contains 30 traffic channels, Timeslot number 0 take over synchronization tasks, and timeslot number 16 contains signaling information.

Traffic Load: The traffic load is determined from the number or volume of calls intensity (λ) and service time (mean holding time) μ.

Traffic can be characterized into the various traffic types as shown below:

- Offered traffic A
- Carried traffic A_c (flow traffic)
- Block traffic A_b (loss traffic)

Offered traffic = carried traffic + block traffic

$$A = A_c + A_b \quad (2)$$

$$\text{Offered traffic } A = \lambda \times \mu \quad (3)$$

λ = Number of calls intensity
μ = Mean holding time (service time)

Traffic load can be affected by various factors such are:

- Area of a cell (reduce the size of cell)
- Number of channels or truck per cell
- Cluster size
- Spectrum efficiency
- Bandwidth per channel

The traffic load cell analysis depends on these factors mention above, the cell technology is homogenous in nature and is therefore applicable to the entire communication network.

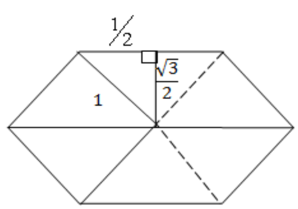

Fig. 4: Geometry of a Hexagon

Area of a Cell: A cell is hexagon in shape; therefore the area of an hexagon should be determined by a set of 12 triangles (Fig. 4):

A triangle is $\frac{1}{2} \times b \times h$
b = Breadth
h = Height

The resultant surface area of a hexagon is $6R^2$ time $\sqrt{3}/4$where R is the radius of a cell. Therefore,

$$\text{Hexagon surface area} = R^2 \times 2.598 \quad (4)$$

Total Bandwidth of a Cell: Total bandwidth for the cellular network (B_S) is the product of the occupied bandwidth per channel (B_T), the number of channels per cell (M) and the cluster size ©:

$$\text{Thus} \quad B_S = B_T \times M \times C \quad (5)$$

B_T = Bandwidth per channel
M = Number of channels per cell
C = The cluster size

The bandwidth per channel depends on the cellular network standard used. For instance GSM standard use 200KHZ as bandwidth per channel, while CDMA2000 standard used 1.25MHZ as bandwidth per channel.

Typical number of channels per cell is 56 channels (Rappaport, 2003).

Cluster size is the total number of duplex channels. The cluster size is an important factor, because decrease in the cluster size lead to decrease in the spectrum efficiency, increase the capacity and increase the co-channel interference from other cells using the same frequency (Gunner, 1998):

$$\text{Cluster size } C = i^2 + ij + j^2$$

For GSM network cluster size is 7, i = 2, j = 1
While for CDMA2000 network cluster size (C) is 3, i = 1, j = 1 (Rappaport, 2003).

Spectrum efficiency: Spectrum efficiency is defined as the traffic that can be handled within a certain bandwidth and area.

$$S_E = \text{Traffic load or traffic intensity in Erlang/ Total bandwidth} \times \text{Area} \quad (6)$$

$$S_E = \text{Traffic intensity in Erlang}/B_S \times A$$

$$B_S = B_T \times M \times C$$

$$\therefore S_E = \text{Traffic intensity in Erlang}/(B_T \times M \times C) \times A \quad (7)$$

Table 1: Traffic Performance Parameters

Routes	Offered traffic in erlang	Call Completion Rate (CCR) (%)	Busy hour call attempts (BHCA)	Grade of service	Channel utilization (%)
1	18.96	99	0.024	0.012	79
2	45.13	100	0.036	0.002	79
3	14.72	99	0.022	0.007	67
4	11.7	100	0.031	0.011	62
5	14.75	100	0.026	0.000	67
6	87.28	100	0.043	0.003	87
7	14.23	97	0.042	0.026	65
8	20.04	97	0.028	0.026	69
9	21.79	88	0.031	0.027	73
10	34.65	88	0.035	0.124	89
11	81.05	90	0.045	0.100	87
12	99.01	94	0.043	0.062	88
13	10.78	97	0.044	0.032	76
14	39.57	99	0.026	0.012	76
15	35.65	99	0.037	0.010	78
16	35.01	96	0.037	0.015	87
17	79.76	98	0.038	0.018	73
18	22.57	98	0.049	0.021	74
19	24.54	100	0.034	0.003	73
20	53.61	99	0.035	0.009	75

Traffic Intenisty = [Number of call (per h) × Average calls duration (sec)]/3600 (8)

Traffic intensity is in Erlang, while Spectrum efficiency is expressed in Erlang per MHz × km^2:

Total number of channel sper cell =

Allocated spectrum/[Channel width × Frequencyreuse factor] (9)

(Juha, 2003 and http://www.computer.org/portal/web/journal/ieee).

METHODOLOGY

This data was obtained for a period of one year using the Operation and Maintenance Center (OMC-counter), as a measuring device to capture and monitor all the traffic activities (event). The type of measurement involved in traffic measurement is the discrete measurement. The traffic event is stochastic (random variable), the stochastic component are:

- Number of calls variation
- Service times variation (Moltchanov, 2005)

Based on the stochastic component obtained, traffic load on the mobile communication network and traffic characteristic was determined. They are offered traffic, carried (flow) traffic and block traffic. Therefore, from the offered traffic, the traffic performance parameters (indicators) such are list below were also determined. They are:

- Call Completion Rate (CCR)
- Busy Hour Calls Attempts (BHCA)
- Grade of Service (GOS)
- Channel Utilization Rate (CUR)
- (Traffic load) offered traffic in Erlang

These traffic performance parameters are used to estimate the capacity and system utilization rate.

The data collected was from Zoomobile Communication Networks in Nigeria. The data was used to calculate the traffic performance parameters for various route, shown in Table 1.

Data presentation: This is average data obtained in a period of one year in mobile communication network in Nigeria, using OMC-counter. The stochastic variables are number of calls and service time. These formed the basic factors used to determine the offered traffic. The offered traffic in Erlang, was used to determine the traffic performance parameters or indicator. Shown in Table 1: For 20 routes.

RESULTS

Data analysis: Results were arrived at using the data in Table 1 to determine the various traffic performance

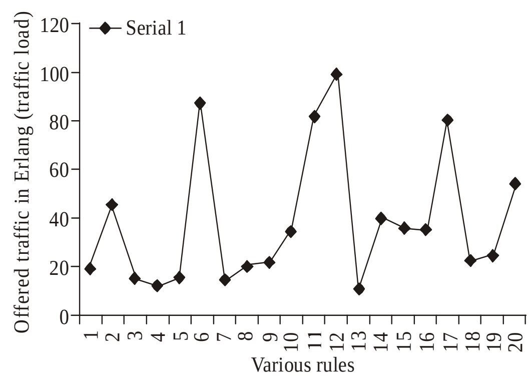

Fig. 5: Offered traffic in Erlang against various route

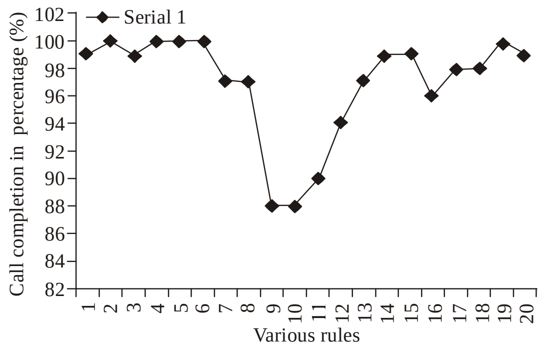

Fig. 6: Call completion rate against various routes

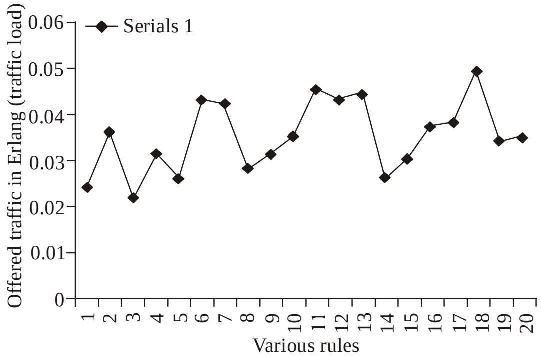

Fig. 7: Busy hour Call attempts against various routes

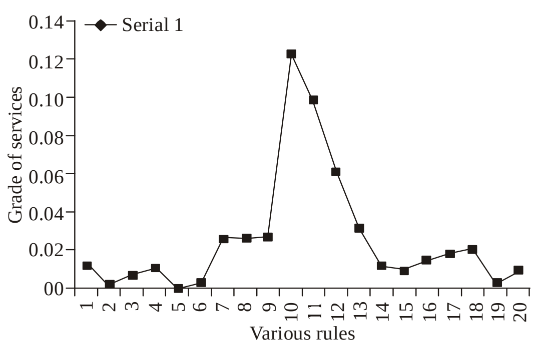

Fig. 8: Grade of Service against various routes

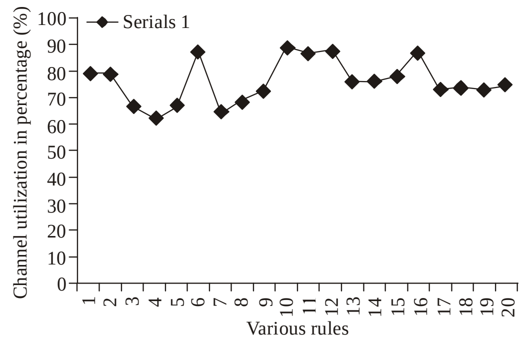

Fig. 9: Channels Utilization against various routes

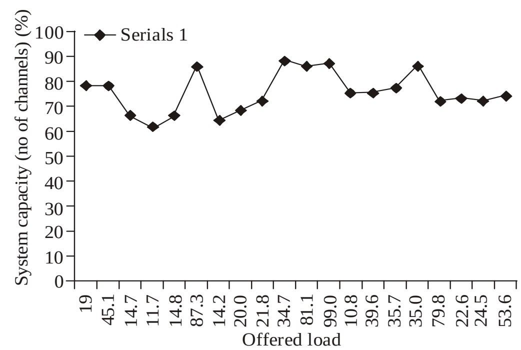

Fig 10: System capacity (No of channels) against offered load with a given grade of service of 0.02

parameters of a mobile communication network. They are shown below from Fig. 5 to 10.

The graph in Fig. 5 shown the offered traffic load for 20 routes in busy hour. Route 12 has the highest traffic load followed by route 6 and routes 11 etc. While route 4 has the least of the lowest offered traffic load. Efforts should be made to increase the system capacity for route 12, 6 and 11 to meet with subscriber demands and to avoid block calls during the busy hours.

The graph in Fig. 6 shown the call completion rate in 20 routes. The call completion rate is a major key in traffic performance. The call completion rates recommended by Nigerian Communication Commission should be greater than 90% from the graph shown above except route 9, 10, 11 and 12 are below recommended level. Effort should be made to improve on these routes.

The graph in Fig. 7 shows the graph of Busy Hour Call Attempts (BHCA) for various routes (20 routes). This parameter is used to determine the traffic performance of a mobile communication system and the value should be kept between 0.2 to 3 for good traffic situation (Traffic Characterization for Mobile Network, 2002). The graph shown that BHCA for various routes are in accordance with NCC standard.

The graph in Fig. 8 shows the grade of service of various routes (20 routes). Grade of Service (GOS) is referred to as the probability of a curve in the circuit group (channel) being blocked (http://www.en.wikipedia.or/wiki/grade-of-service):

$$GOS = \text{Number of lost calls} / \text{Total number of offered calls}$$

The Nigerian Communication Commission (NCC) recommended value for Grade of Service is 0.02 or 2%. The graph shown that various routes are in-line with NCC recommendation. But routes 7, 8, 9, 10, 11, 12, 13 and 18 Grade of Service are above the specified value, therefore these routes may likely experience block calls during the busy hours.

The above graph in Fig. 9 show the channel utilization of various routes. Based on NCC recommendation, the channel utilization rate should be less than 60%. From the graph all the channel utilization rate are greater than 60 percent which will result in block calls during the busy hour.

The graph in Fig. 10 shown the relationship between the system capacity (No of channels) with offered traffic load, while the grade of service of 0.02 remained constant. The system capacity deduced for the offered traffic load was between 60 to 90% usage. From the graph any slight increase in offered traffic will result in block calls during the busy hour.

DISCUSSION

Nigerian Communication Commission are empowered by Nigeria constitution to regulate mobile communication network. Some recommended standards from NCC are listed below:

- Grade of Service (GOS) £ 0.02 or 2%
- Call Completion Rate (CCR)³ 90% or 0.9
- Channels Utilization Rate £ 60%
- Block Calls £ 0.02
  (http://www.NCC.gov.ng)

When this NCC standard compared with various result obtained, there was a slight displacement from a recommended standard and this will result in block calls during the busy hour.

CONCLUSION

Based on the research work and the data obtained from the OMC-unit of the Mobile Communication Network in Nigeria. Traffic cell analysis was carried out, traffic characteristic was determined and also traffic performance parameters. They are offered traffic in Erlang in Fig. 5, route 12 has the highest offered traffic load followed by route 6 and 11. Effort should be made to increase the channel capacity to avoid block calls. Call Completion Rate (CCR) in Fig. 6, route 9 and 10 are far below recommended value by NCC, therefore an improvement should be made on those routes. Busy Hour Call Attempts in Fig. 7, all the routes are in a good order between 0.2 - 3. Grade of Service in Fig. 8, routes 7, 8, 9, 10, 11, 12, 13 and 18 may likely experience block calls due to the high value of grade of service. Channel Utilization Rate in Fig. 9, all the values utilization is above 60% recommended value, therefore effort should be made to reduce utilization rates below 60% to avoid block calls during the busy hour and Channel Utilization Rate with the corresponding offered traffic in Erlang in Fig. 10. It was shown that all the Channel Utilization Rate usage is above 60% recommended by NCC. Therefore efforts should be made by network operators to improve on their quality of services (QOS) especially those mentioned routes. An appropriate authority should ensure that operators conformed to the regulated standards to avoid block calls in busy hour.

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