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ANALYSIS ON TRAFFIC CONGESTION IN TELECOMMUNICATION USING NITEL AS CASE STUDY

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ABSTRACT

This paper is a detailed analysis of traffic in Public Switched Telephone Network or system (PSTN). Using Nigerian Telecommunications (NITEL) as case study for the month of February, 2005. A comprehensive evaluation of traffic congestion along three routes were analyzed i.e. Abuja to Kaduna, Abuja to Bauchi, Abuja to Benin during the busy hour in relation to Availability, Dimensioning, Lost call, Call completion ratio, Erlang, and Grade of service was carried out.In view of this an insight was given into the types and forms of switching, signaling, and the type of switching equipment majorly used by Nigerian Telecommunication (NITEL). Based on the data and physical observation it was seen that the performance of an exchange is been determined by the Grade of service (probability of meeting congestion) the lower the grade of service, the lower the blocked calls. The call completion ratio increases with decrease in Grade of service. The higher the Call completion ratio of an exchange the lower the Grade of service.

INDEX TERMS – Public switched telephone network (PSTN), Traffic Congestion, Grade of service, call completion ratio.

INTRODUCTION

Traffic is any type of load imposed on a system, which is supposed to be carried by the system. For example road traffic, railway traffic, telephone traffic. In an office the number of files given to a clerk for disposal is a kind of traffic. In telecommunication voice, data and images in the form of electrical signals which is transferred from one telecommunication equipment to telecommunication equipment through telecommunication network is defined as telecom traffic.

The condition of a network where the immediate establishment of a new connection is impossible owning to the unavailability of network elements is called traffic congestion in telecommunication network. It may be momentary for an unusually high traffic. Accumulation of traffic in any portion of network is called traffic congestion.

Due to the large number of subscribers that require service simultaneously at *a* particular point in time a subscriber may not be able to make his call or originate a call because all the connecting equipment are busy. In this case, the subscriber is said to have met congestion. Only a small portion of subscribers will be using their telephones at any time, even during the busiest hour. The probability of a subscriber to make a call is completely uncertain. But the system is made always ready for a response to the subscriber. It is so uncertain that sometimes a huge number of calls are accumulated. Either calls are lost or held in queue or some times there is no call so that a portion of the network remains idle.

There are 2 types of congestion, Time congestion which is the ratio of time for congestion to the total time for congestion also the call congestion which is the ratio of number of call attempts which cannot be matured immediately to the total number of call attempts[1]. Congestion occurs for various reasons depending on switch facilities, exchange equipment and transmission link Traffic congestion mainly occurs due to inadequate capacity of equipment and improper network management.

Causes of congestion may be classified as follows: congestion due to faulty equipment, congestion due to generation of high traffic, congestion due to improper configuration of network.

CONGESTION DUE TO FAULTY EQUIPMENT

It means the use of faulty equipment to carry traffic. The load is transferred to faulty equipment. When a switching equipment fail to process a call, a subscriber try again and again. As a result, traffic increases and congestion occurs. Moreover faulty equipment faces congestion more than that of a good one. Failure of transmission equipment may cause congestion to the switching equipment as the traffic stored in the memory of the stored program controlled switching system is increased.

CONGESTION DUE TO GENERATION OF HIGH TRAFFIC

A sudden increase in originating and terminating call can cause traffic congestion. Traffic may be increased in a particular area due to natural disaster like flood, earthquakes and accident [1]. It may also be due to manmade situation like accidental explosion, mass agitation, strike, political gathering or failure of electric supply system. Generation of high traffic may be caused by the time of the day, the seasons and periods of the year and the location of the exchange. It is being observed that during the festival seasons of the year traffic is always heavier than

during the other days of the year.[2] An exchange that is sighted in an industrial area or location will experience a huge traffic during the working hours and a light traffic during the evening or night.

CONGESTION DUE TO IMPROPER CONFIGURATION OF NETWORK

Sometimes there appears congestion in a portion of a network while there is idle equipment in another portion of a network. Particularly in transmission links, one link may be in congestion while another link remains idle. In this case overflow traffic from one link may be transmitted through alternate link via transit to another node. Due to failure of one link, the traffic may be re-routed to another link and causes congestion to that link.

Traffic congestion is a big problem to engineers. The object of teletraffic engineering is to formulate a set of procedure for the design and day to day management of a telecommunication system that will result in the most economic provision of telecom switching equipment and trunk circuit subject to providing a satisfactory service at an acceptable cost to the user of the system.[1]

REVIEW OF TECHNIQUES USED IN CARRYING TRAFFIC

SIGNALING

In a switched telephone network signaling is needed to tell the exchange that a subscriber desires service and to give the local switch the data necessary to identify the required distant subscriber and hence properly route the call. It provides supervision of a call along its path.

Furthermore, signaling gives the subscriber certain status information such as dial tone, busy tone and ringing. Thus signaling is the nerve system that makes telecommunication network a reality. In general sense signaling function begins with the acceptance of information from source, followed by encoding process, signal generation, signal transmission, signal detection, signal decoding and eventually delivering the information.

SWITCHING

Switching is the means of allocating resources such as space, bandwidth or time to people or machine that use the resources to facilitate communication at a distance. The overall function of any telecommunication switching system is to connect two or more terminals. The switching element normally referred to as cross point, is a device that enables a physical connection to be made in order to establish the transmission path for voice or data signal. The simplest form of switching element is a metallic device such as a relay which when instructed brings two pieces of conductors together.

As technology advanced from normal relay to digital integrated circuits the option available for the switching element has increased considerably. It should be noted that the choice of switch element dictates the transmission mode and thus the overall switch configuration.

The first communication switch facilities were manually operated switchboards. Everyone in communication field is aware, at least to some extent of the history of telephone switching from manual system through numerous types of electromechanical system to the current variety of stored programme control (SPC) electronic switching systems.

As a result of the success of digital transmission from the point of view of low cost and low maintenance cost, interest emerged in the late 1960's in switching system which could interconnect in digital form. This marked the beginning of digital switching era.

A digital switching system may be viewed as one in which analogue information is converted to digital form for switching through electronic logic gates or memories. There are two major components of such a system namely the switching system and the control. There are two basic techniques for accomplishing the switching of communication or channels that are in common use. They are space division switching and time division switching.

SPACE DIVISION SWITCHING

In space division switching a continuous physical path is set up between the input and output channels. This is done by connecting end-to-end a number of path elements called links by means of a device known as cross points. Each cross point has two states: closed (conducting) or open (blocked). It may be electronic chemical device or semiconductor device.

Once the continuous path has been established signal may be transferred between the two channels. Each path (link and cross point) is assigned to one call, and exclusively to that call through its duration. Cross points are arranged in rows and columns to form matrices. Any row can be connected to any column by closing the corresponding cross point.

Space division switching can be likened to FDMA (frequency division multiple access) in which channels are allocated according to frequency bandwidth and a channel is only in use at a time until a channel the channel is free for another call to be set up i.e. no two channels can be used for more than one call at a time.

TIME DIVISION SWITCHING

Time division switching is a technique where the signal or channel to be switched is sampled at such a rate as to ensure that all the information in the signal is contained in the samples (NYQUIST RATE) and these samples are interleaved in time and subsequently reassembled to reconstruct the original signal.

Two fundamental techniques pulse code modulation (PCM) and delta modulation (DM) are widely known for coding human voice and video to digital time division multiplex (DTDM) formats for the purpose of transmission and switching is likened to TDMA (Time division multiple access) in which the

frequency bandwidth could be used by the same channel but at different time slot i.e. the same channel can be used to make calls but at different times.
The types of digital switching that we have are the message switching, the circuit switching, the packet switching and the electronic switching system. Only the electronic switching system will be discussed.

ELECTRONIC SWITCHING SYSTEM

The invention of transistor and IC's (integrated circuit) followed by the advent of bulk electronic memory created a tremendous new potential for switching.

Electronics switching involves the use of reed relays for the interconnection of network and it uses electronics for all the major control elements. It uses a single (but duplicated) processor for handling all calls and also use stored program for controlling the exchange

The major advantage of electronic switching system was stored program control which made it possible to add certain features such as call back facilities, reverse-change operation principally by designing new software.[2]

ALCATEL SYSTEM 12

Using the most advanced technology, system 12 is designed to provide an administration and its subscribers with efficient and reliable services. Subscribers not only require a reliable service, they require a wide range of facilities which benefits both business and private usage.
The alcatel system 12 is a type of switching equipment that uses electronic switching system (ESS) for its mode of operation. It is digital switching equipment which also is a DTMF (dual tone multi frequency) operated.

It is the most widely used switch today. The name alcatel system 12 indicates the name of the manufacturer "ALCATEL" and the equipment is being used by the Nigerian telecommunication limited (NITEL) for their digital exchange and their transmission (digital) system.[3]

THE ERLANG

The traffic flow or intensity is an aggregate of telephone calls over a group of circuits or trunks with regards to the duration of calls as well as their number. We can say that the traffic flow

$$A = C \times T \qquad (1)$$

Where C is the calling rate and T is the average holding time

The unit of A is call-minute or call-hours. For example say the average holding time was 2.5mins and the calling rate in the busy hour for a particular day is 237. Traffic flow A yields 237 x 2.5 = 592.5 call-minutes (cm).The preferred unit of traffic is erlang, which is a dimensionless unit which was named in honor of the Danish pioneer traffic theorist Agner Krarup Erlang (1878-1929). By definition Erlang is the number of call-seconds per seconds or the number of call-hour per hour. Thus if a group of 10 circuits is known to have a call intensity of 5 erlangs, then half of the circuit will be expected to be busy at the time of measurement while the other half are free.

Note that there are other traffic units which are not as dimensionless as the erlang. We have the CCS (cent call per second), we have the EBCH (equated busy hour call)

1ERLANG = 30EBCH = 36CCS = 60CMIN.

DIMENSIONING

Dimensioning is determination of the number of trunks required on route or connecting between exchanges.

To dimension an exchange a route or traffic path it is necessary to have some idea of its usage in terms of the number of people that may wish to talk at once over the route. The usage of transmission route or switch brings us into the realm of traffic engineering.

CONGESTION, LOST CALL AND GRADE OF SERVICE

Suppose an exchange is to serve 10,000 subscribers and no more than 10 percent of the subscribers would require service simultaneously. Such an exchange can be dimensioned with sufficient equipment to complete 1000 simultaneous connections, with each being a connection between any two subscribers. Suppose subscriber 1001 attempts to originate a call he will be unable to do so because all the connecting equipments are busy, and even though the subscriber he wishes to reach may be idle .The call from the 1001st subscriber is termed a LOST CALL or BLOCKED CALL.

The subscriber is also said to have met congestion. Note that the lost call or blocked call refers to call refers to calls that fails at first attempt. Reattempts are not considered in determination of the GRADE OF SERVICE which is the probability of a subscriber meeting congestion i.e. probability of congestion. It is denoted by P = 0.01, meaning that an average of one call in 100 will be blocked or lost during the busy hour. Congestion conditions are expected during the BUSY HOUR. [2]

SOLUTION METHODOLOGY

TRAFFIC LOAD MEASUREMENT

Traffic load is the ratio of call arrival in specified period of time to the average amount of time taken to service each call during that period. Before this can be calculated, the average hold time (AHT) must be determined by calculating the ratio of the total time of
All calls in a specified period divided by the number of calls in that period. It is mathematically represented as shown below:

$$AHT = \frac{\text{Total call seconds}}{\textit{Number} \text{ of calls}} \qquad (2)$$

The SI unit of AHT is seconds.

Having known the AHT, the traffic load can then be measured using the relation;

$$Traffic\ \text{Load} = \frac{\text{number of calls} \times \text{AHT}}{3600} \quad (3)$$

And this is measured in Erlang.

In telephone system, traffic load is commonly measured in centum call seconds or cent call seconds (CCS). This relation is used as follows;

$$Traffic\ \text{Load} = \frac{\text{number of calls} \times \text{AHT}}{100} \quad (4)$$

Both units (Erlang and CCS) are recognized by International Telecommunication Union (ITU). The relationship between the two units makes it possible to easily traverse from one to another and it goes thus:

1 ERLANG = 36 CCS

$$\text{AND } 1\text{CCS} = \frac{1}{36}\text{ERLANG}$$

The network traffic load is usually measured during the busiest hour of the day because this period represents the maximum traffic load that the network must support. The result gives a traffic load measurement commonly referred to as the busy hour traffic (BHT) .This helps in determining the trunk requirement without having more complete data by making assumptions about the environment such as average number of calls per day and the AHT.

In telephony, there are various ways for measuring the network capacity but the most paramount ones are:

- busy hour call attempt (BHCA)
- Busy hour call completion (BHCC)
- Calls per seconds (CPS)

All the methods are based on the number of calls.

GRADE OF SERVICE

This is the probability that calls will be blocked while attempting to seize the circuit which is usually encountered during the busy hour and is the probability of meeting congestion during the busy hour. It is often referred to as Blocking factor or blockage and is function of percentage of calls that are blocked for a traffic system. In telephony the blocked calls refers to calls that fail at first attempt. Reattempting is not considered in determination of Grade of service. It is determined by dividing lost call (the number of blocked calls) divided by the number of offered calls.

$$\text{congestion} = \frac{\text{Number of Lost calls}}{\text{Total number of offered calls.}} \quad (5)$$

For a network, the average grade of service can be obtained by adding the grade of service contributed by each element (switch, switching network, trunk group). In order to have a zero grade of service (that is there exist no blocking call), then the network should be described in such a way that the caller to circuit ratio is 1:1, but it might not be economically feasible. Since the calling rate by the subscriber has been observed to be random, a means of interconnecting subscribers is created. This permits the shared use of resources which increases servicing and at the same time cost effective. This process is known as switching.

TRAFFIC TYPES

The Telecommunication equipment offering that is offering the traffic can be used to record the data. Unfortunately most of the sample received is based on the carried traffic on the system and not the offered traffic load.

The difference between the carried traffic and the offered traffic determines the amount of blockage that can be experienced on the telecommunication equipment during the busy hour.

$$Offered\ \text{Traffic} = \frac{\text{Carried Load}}{1 - \text{Blocked factor}} \quad (6)$$

The above formula does not cater for the retry. For more accuracy the retry rate is considered and the offered traffic can be calculated as shown below;

Offered load = carried load x offered load adjustment factor (OAF)

Where

$$OAF = \frac{[1.0 - (\text{R} \times \text{blocking factor})]}{1.0 - \text{Blocking factor}} \quad (7)$$

And blocking factor is the grade of service

R is the percentage probability.

THE SAMPLING METHOD

The accuracy in the measurement of traffic depends largely on the accuracy of the sampling methods. The public switched telephone network (PSTN) connection measured or read out period is 60 minutes and/or 1 minute as recommended by the ITU. NITEL Ibadan Transmission room uses both 15 minutes and 60 minutes for traffic analysis

The two recommended ways to determine the peak daily traffic is as follows:

i) Daily Peak Period (DPP): This record the highest traffic volume measured during a day. This method requires continuous measurement and is typically used in environments where the peak hour may be different from day to day.

ii) Fixed daily measurement: This requires measurement only during predetermined peak value periods occurring at regular intervals. Business traffic is usually peak around 10.00am to 3.00pm. [2]

TRAFFIC ANALYSIS

This aspect deals with the evaluation of the factors affecting traffic i.e. its analysis. These factors were described in chapter three and they depend on the sampling period which may be 15 or 60 minutes as

adapted by NITEL switching center, Abuja. The sampling period is also known as scanning output period. During the sampling period different readings and measurements were taken.

During the course of this project three routes are monitored they are Abuja to Kaduna, Abuja to Bauchi, Abuja to Benin respectively.

METHODS USED IN ANALYSIS OF TRAFFIC

i. Practical approach
ii. Theoretical approach

PRACTICAL APPROACH

$$Total\ Erlang = \frac{occupancy}{Trunks\ available} \quad \text{.....4.1}$$

$$Erlang/cct = \frac{Total\ erlang}{Trunks\ available} \quad \text{.....4.2}$$

The Erlang/cct was calculated during the busy hour using Equation 4.2 for Abuja to Kaduna route, Abuja to Bauchi route and Abuja to Benin route as shown in Figure 1.

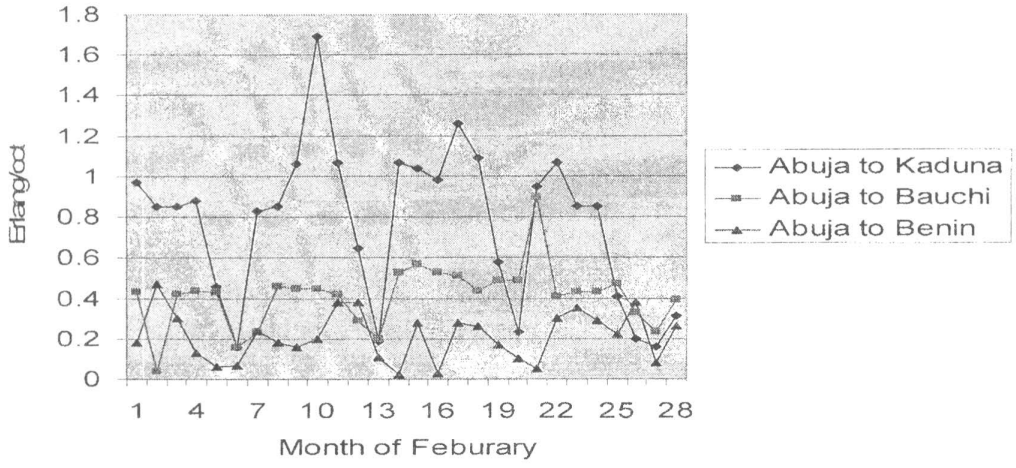

Fig. 1 : Traffic behavior during the busy hour at NITEL (Abuja).

To calculate the call completion ratio

$$CCR = \frac{Answered\ \ call + No\ \ reply \times 100}{Attempts} \quad \text{.....4.3}$$

$$= \frac{Ans\ call + No\ reply + S\ busy + Incop.Dial \times 100}{Attempts\ \ (Bids)} \quad \text{.....4.4}$$

The Call Completion Ratio during the busy hour was calculated using Equation 4.4 for Abuja to Kaduna, Abuja to Bauchi and Abuja to Benin route as shown in Figure 2.

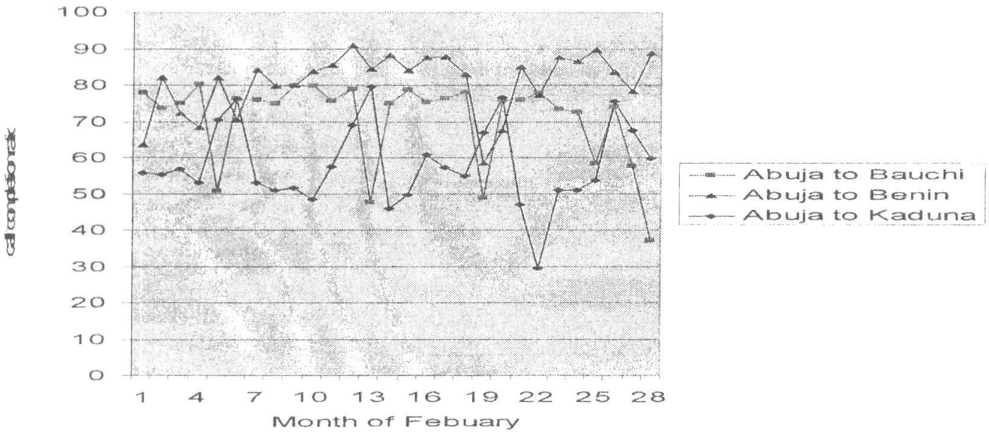

Fig. 2 : Call Completion Ratio at during the busy hour at NITEL(Abuja).

To calculate the Grade of service (GOS) which is the ratio of lost calls to the offered call

Carried call = Answered call + No reply

Offered call = Attempted call

Lost call = Offered call- Carried call

$$GOS = \frac{ATTEMPTS - CARRIED\ CALL}{ATTEMPTS} \quad (4.5)$$

The Grade of Service was calculated during the busy hour using Equation 4.5 for Abuja to Kaduna, Abuja to Bauchi and Abuja to Benin route as shown in Figure 3.

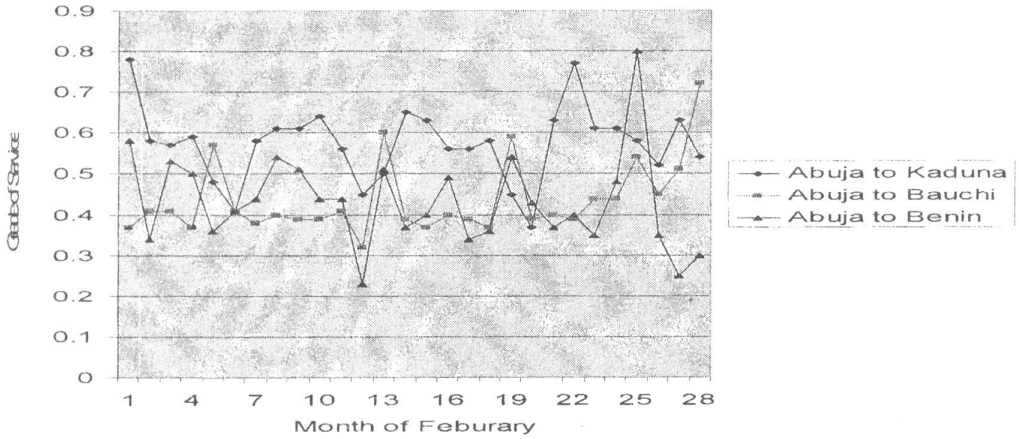

Fig. 3 : Grade of Service during the busy hour at NITEL(Abuja).

THEORETICAL APPROACH

This is another way or means of analysing traffic that involves using standard Erlang table to evaluate or measure traffic In telephone system,.there are three parameters used in which two of them must be known to determine the third one.The parameters are :

- Number of trunks (N)
- The Erlang (A)
- The Grade of service (B)

From Table D, if we have the number of trunks(N) = 30 for 0.4 Grade of service,the point of intersection of N = 30 and B = 0.40 on the Erlang table gives the value of the traffic(Erlang)= 47.735. Also, if the number of trunks (N)= 21 and Grade of service(B) = 0.2, the point of intersection of N= 21 and B= 0.2 gives the value of traffic (Erlang)=22.848.[4]

DISCUSSION OF RESULTS

The traffic was compared for three different routes for the month of Febuary, 2005 i.e Abuja to Kaduna , Abuja to Bauchi and Abuja to Benin.

The Call Completion Ratio shows better performance of the exchange when it is at high value and this depend on the number of occupied circuits. Abuja to Benin has the highest CCR values for the month of feburary followed by Abuja to Bauchi and the least is Abuja to Kaduna which shows that Benin exchange has the best performance for the month of Feburary since it has the highest CCR.

Deducing from the graph, (i.e Figure 1) it was shown that the number of trunks (N) varies in direct proportion to the Erlang (A) i.e increase in the value of the number of trunks provided for an exchange results to corresponding increase in the traffic (Erlang) for the exchange.

Also the number of trunks varies inversely as the Grade of Service (probability of meeting congestion) i.e the higher the value of trunks provided the lower the value of the Grade of service (i.e the less the probability of meeting congestion) as shown in Figure 3.

The evaluation and measurement of traffic has shown that there is greater rate of congestion in Abuja to Kaduna than for Abuja to Bauchi or Abuja to Benin because the route has the highest values of grade of service. This shows that Abuja to Kaduna route is overutilised bacause it is a metropolitan area where there are more settlement functions such as official, commercial and educational facilities than that of Abuja to Bauchi or Abuja to Benin.

The Grade of Service is the major factor considered when dimensioning an exchange, because it determines the size and capacity of the equipment to be installed to a particular exchange (area). The level of performance in Abuja to Bauchi and Abuja to Benin is still okay, i.e cannot be said to be overutilised or underutilised.

In the theoretical approach it was said by Roger Clery of Roosevelt University that there is probability of error outside the first fifty number of trunks (N) available as a result the Standard Erlang Table has fifty number of trunks and any other number of trunk (N) greater than this has a probability of error and as a result this method (i.e. theoretical approach) is not applicable if the number of trunks exceeds fifty.[4]

The effect of faulty circuit in traffic measurement results to the inaccuracy in measurement and as such, there is need to rectify the fault as soon as possible.

CONCLUSION

It could be seen from the analysis of the result that the performance of an exchange is being determined by the grade of service(GOS).The lower the value of the grade of service,the lower the blocked calls(spillage) which symbolises a good performance

in the exchange. The value of the grade of service ranges between one and zero since it is the probability of meeting congestion in the equipment (at the exchange) during the busy hour. The negative value of the grade of service cannot occur in practise because carried traffic cannot be greater than the offered traffic, if the initial condition is set to be zero, but its occurrence is as a result of greater value of call spillage.

The call completion rate increases with decrease in grade of service. The higher the call completion rate of an exchange, the lower the GOS. The result of other analysis has shown that the seizure / attempt disparity and high percentage call completion ratio is as a result of call spillage from one scanning output period to the other and overflow arising from the alternative routes.[5]

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