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Congestion Management on GSM Networks using Traffic Class Prioritization

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***Abstract*— Congestion remains a major challenge to GSM service provision both to the service providers as well as the subscribers. This work determines an efficient way to manage congestion effectively in GSM Networks during peak periods using the developed traffic-class prioritization algorithm. Performance evaluation of the algorithm showed that real-time traffic has better preference over non- real-time traffic and that optimum efficiency is achieved during congestion periods when it is used. Further research was recommended to include handoff scheme in the algorithm and to implement the algorithm on a higher level network node such as the base station controller (BSC).**

Keywords— ***Congestion, Efficiency, Management, Prioritization, Queue, Service Rate, Traffic Class***

I. INTRODUCTION

The Nigerian mobile industry has experienced a tremendous growth since its inception in 2001. Its core objective is to provide good quality of speech, effective roaming across countries and friendly tariffs. Exponential growth in subscription has left the operators with the challenge of how to provide reliable services to subscribers amidst subscription congestion. Congestion occurs when the amount of calls/data coming in or calls/data coming out from a specific network is greater than the capability of the network at that particular time [1]. This leads to a wait-in-line for services on the transmission channel. As a result of these, the degree of voice and data transfer is degraded and/or the signal quality obtained becomes faint. The worst case is that the calls may not be connected to the intending receiver.

In recent years, the use of wireless data networks has increased tremendously with the use of smartphones and mobile broadband [2]. Many experts have forecasted that voice traffic growth will remain at a steady state whereas data traffic will increase strongly in all regions of the world. The use of mobile networks to access the internet and the increased usage of data services by subscribers have been a contributing factor to the congestion been experienced on the networks [3].

While there are several research works that have attempted to manage congestion on the Global System for Mobile Communications (GSM) Network using different schemes, only few have tried to use prioritization techniques to control congestion. This necessitated the development of a more efficient way to manage congestion during peak periods by prioritizing the different categories of data traffic that transcend the network.

II. CONGESTION ON GSM NETWORKS

Congestion occurs when blocking of service requests occurs such that an offered service cannot be provided a free channel [4]. It is mostly caused by traffic overflow [13]. Network congestion can occur when a rise in the transmission of data leads to a decrease in throughput. This situation is as a result of applications sending more data than the network elements can accommodate thus causing the buffers on the network elements to be filled and possibly overflow [3]. According to [4], congestion is a state of sustained network overload. In queuing theory, traffic congestion occurs if the rate of arrival into a system exceeds the particular service rate of the system at a moment in time [5]. When particular requested network services are unavailable to the subscriber [6], signals queue on the transmission channel and either the transfer rate of the signals become low or the quality of received signal becomes faint, which could lead to a worst case of denial of service to the subscribers [6].According to [7], congestion is a condition that arises when the number of packets being transmitted through the network approaches or exceeds the packet handling capacity of the network. In summary, congestion is often a situation that arises when the volume of service requests emanating from or being implemented in a particular network is more than what can be handled at that particular time [8]. Congestion on the GSM network can be experienced along several channels within the network architecture. Congestion occurs when the common, dedicated, traffic and Pulse Code Modulation (PCM) channels are not available for assignment to incoming or outgoing service requests [6]. Congestion could also occur when backbone links fail leading to available links been over utilized.

III. RELATED WORKS

A number of related works exist in the area of congestion management in GSM Networks. Venkataramani and Rajeswari [9], focused on the evaluation of the performance of four queuing disciplines which include First-In First-Out (FIFO), Priority Queuing (PQ), Random Early Detection (RED), and Weighted Fair Queuing (WFQ), implemented in AEERG protocol. The operational aspects of these scheduling disciplines were highlighted. Network simulator (NS-2) software was utilized for the simulation of the proposed algorithm by measuring traffic throughput and packet delivery ratio. It was established that WFQ is better where computational load is limited, it is also better in terms of service delivery ratio and throughput but it presents scalability problems and cannot be used in high traffic environment requiring many classes of service. The paper concluded that combination of the queuing disciplines reduced consumption of energy and increased reliability.

According to Briscoe, Menth, and Tsou [10], the concept of Pre-Congestion Notification (PCN) based admission control and termination of flow was discussed. Benefits and limitations were also highlighted. A combination of admission control and flow termination using Explicit Congestion Notification (ECN) to achieve a better scheme was done. It asserted that the combination allows economical provisioning of transport networks. However, the scheme is unable to support advance reservations and multi-paths. The work did not put the different traffic classes into absolute consideration.

Regitha [1] proposed Carrier Sense Multiple Access / Collision Avoidance (CSMA/CA) for reducing congestion in wireless networks. The work recommended a multiple channel access mechanism that used CSMA/CA to reduce congestion in cellular networks. The work employed utilized the use of buffer administration techniques, reduction of the rate at which the base station informs the mobile station to transmit data and the increase in the use of channels per cell. The work also used parameters like Request to Send (RTS) and Clear to Send (CTS) to achieve the purpose of the study. However, the work did not consider the difference in the category class of services available.

Alarape, Akinwale, and Folorunsho [11], proposed a scheme which includes a load balancing technique and Call Admission Control (CAC) in order to reduce the rate of network congestion and signal quality degradation. CAC, dynamic load balancing and shortest path algorithm were used. The performance evaluation was done using new call blocking and handoff call dropping probabilities. Better performance was achieved in that regard but the aspect of data transmission was not considered in the work. The work recommended enhancement should of other BSC areas could as well be done and that heterogeneity in networks could be considered also.

Kuboye, Alese., and Fajuyigbe [12], proposed an optimization model for reducing the problem of traffic congestion on the GSM network. Authors revealed that the use of dynamic half rate reduces the required amount of data for each user and that there will be capacity expansion and improved coverage through merger of the existing networks. The work concluded that the models presented would help the GSM operators to deliver good and quality services. The author did not consider data service interaction in the work.

This paper proposes a hybrid class prioritization algorithm for traffic congestion management in GSM Networks by making it possible for packets from real-time data traffic to be admitted and serviced more frequently than packets from non-real-time data traffic during congestion periods while ensuring that the non-real-time data traffic are not starved in the process.

IV. TRAFFIC CLASS PRIORITIZATION

Traffic class prioritization is a Quality of Service mechanism where categories of data traffic are assigned priority values according to their class of service (CoS) and these values are used by the network scheduler to effectively manage resource usage on the network during congestion periods. This work presents a more effective method of managing congestion through the use of traffic class prioritization. It identifies the different classes of data traffic and manages the available resource to effectively handle the traffic demand.

The utilized traffic classes are Streaming, Conversational, Background and Interactive classes. Delay sensitivity is the main feature that differentiates these traffic classes. The conversational class encompasses traffic that has high delay sensitivity while the traffic class that has the lowest delay sensitivity belongs to the background class [13]. Real time traffic belongs to either conversational or streaming class. Examples of conversational class traffic include telephony speech, voice over IP, video conferencing while examples of streaming class traffic are streamed video or audio. Real-time conversations are mainly performed between multiple humans so the required characteristics are strictly provided by human perception [14]. Non-real time traffic belongs to either interactive or background class. They are both delay insensitive but require high throughput and less error rate. Examples of interactive class traffic include web browsing, database retrieval, access of client to server while examples of background traffic are telemetry and e-mailing. The actual difference between background and interactive class is that background class is employed for background software applications while interactive class is employed for interactive software [13]. The various classes by priority values are shown in Table 1.

Prioritization of service/class can be carried out by using a different admission technique per class such that the class/service with lower priority could have more strict admission policies. Meanwhile, different classes exist for every service and these classes are controlled as outlined by their priority. The priority level is used to allocate resources to the classes/services. A request is rejected if it is discovered that reserved resources for its service/class are not enough.

TABLE.1. TRAFFIC CLASSES AND CHARACTERISTICS

Traffic Class	Characteristics	Priority	Examples
Real-time Conversational	Delay sensitive, Low latency and Jitter	High	Voice and Video over IP.
Real-time Streaming	Limited tolerance to loss, low latency and jitter	Medium	Audio and Video Broadcasts
Near Real-time Interactive	Error-sensitive, best effort, low packet loss.	Normal	Web Browsing
Non Real-time Background	Best effort, loss tolerant	Low	e-mail and file transfer

Through traffic classification, policy management and priority queuing, the network operator exerts some control over the way traffic flows on the network allowing time-critical and delay- sensitive traffic to have priority over other, less time-sensitive traffics.

V. PROPOSED TRAFFIC CLASS PRIORITIZATION ALGORITHM

The developed algorithm consists of congestion detection and resolution strategies using traffic class prioritization. Simulation was done at abstract level by using OPNET software to model the system. In the simulation, the size of each traffic class being successfully transmitted for a period of time was measured, in cases when the algorithm is in use and when not in use. The proposed algorithm observed to be a more efficient and cost-effective way to manage congestion on a GSM Network. The Pseudo-code for the algorithm is shown Fig 1.The following schemes were implemented.

1. There is a queue for each traffic class. Traffic belonging to a class joins the queue meant for that class. Each queue has a limit which is based on the amount of packets it can accommodate.
2. On each queue, First-In, First-Out (FIFO) strategy is used since they are of the same priority so traffic on the queue is served according to their time of arrival.
3. There are rules that govern each class, so requests belonging to a class are subject to those rules. An example is queue limits and bandwidth.
4. Class Based Queuing (CBQ) facilitates flows with different bandwidth requirements assigning each queue a weight value that assigns it a unique portion of the output bandwidth. The queue for high priority classes are given more weight than that of the low priority classes so more service requests from the first two classes are serviced than the other two classes in order to prevent starvation of lower priority classes.
5. CBQ also supports variable-length packets making sure that flows with larger packets are certainly not allocated all the bandwidth at the expense of smaller packet flows.
6. DWRR defines a scheduling discipline which uses *Weight* which is the portion of the total bandwidth assigned to the queue, *Variable Deficit Counter* which is the total amount of data that the queue is allowed to transmit every time it is visited by the scheduler and *Quantum* which increases the value of the Variable Deficit Counter at every round of visit by the scheduler. Each queue is visited once per round, but more attention is given to each class according the weight attached to the class. This means that for every low priority class served, more of high priority class is served likewise.
7. Packets belonging to a high-priority queue are to be scheduled before packets in lower-priority queues only if the volume of traffic in the high-priority queue does not exceed a user configured level.
8. The deficit weighted rounded robin (DWRR) accurately sustains the weighted fair circulation of bandwidth when serving queues that includes variable length packets.

```
    Supposing that there is a Queue set Q = {Q0, Q1, …, Qn};
    W(Qi) indicates the weight of Qi;
    i indicates the queue selected;

  Service Queue [i......n] according to PQ and CBQ
    Enqueue packet to Queue [i]
    END Enqueue

  Dequeue (Queue(i))

   WHILE (TRUE) DO
          IF (active list is not empty)
          THEN i= the index at the head of the active list
          Deficit Counter [i]= Deficit Counter [i]  + Quantum [i]
   WHILE (Deficit Counter [i] > 0 AND  (Queue(i)) NOT Empty DO
          Packetsize= Size (Head(Queue[i]))
      IF  (Deficit Counter [i] >= Packetsize ) THEN
          Service Packet at head of Queue [i]
          Deficit Counter [i]= Deficit Counter [i] - Packetsize
     ELSE MOVE to next non-empty queue
      END IF
   END WHILE
     IF (Queue(i)) Empty THEN
        Deficit Counter [i] = 0
        MOVE to next non-empty queue
     ELSE
         Insert Active list (i)
     END IF
  END WHILE
END Dequeue
```

Fig. 1. Pseudo-code for Hybrid Traffic Class Prioritization Algorithm

VI. PERFORMANCE EVALUATION

To obtain the network performance by simulation, OPNET Modeller 17.5 has been used to implement the different class combination scenarios. This tool has well defined user interface and a rich set of modules where users can efficiently create suitable simulation environments by drag-and-drop of needed object modules. OPNET Modeller can be used to model different kinds of network technologies. In order to evaluate performance of the algorithm over the network, the traffic class service rate was used as the metric for the evaluation.

The designed simulation model was used to evaluate the performance of the algorithm for the various traffic classes in the network. Three scenarios were created to evaluate the performance of the algorithm. The first scenario is the network with the developed algorithm and the other scenarios simulate the network with a combination of different queuing algorithms. Evaluating performance, the IP-QoS attribute was imported to implement the algorithms in the network. Using hybrid of different queuing schemes (Weighted Round Robin (WRR), Priority Queuing (PQ), and Class Based Queuing (CBQ)), it was observed that the queuing mechanism in the developed algorithm obtained a better performance by allowing more of real-time traffic to get serviced and prevents inappropriate starvation of non-real-time traffic.
The results of the simulation rounds were exported and collated from the discrete event simulation module of OPNET. The amount of data packets of each traffic class that were successfully serviced in the scenarios was recorded and presented Fig 2, Fig 3 and Fig 4. Fig 5 shows comparison of the simulation results in relation to packets served.

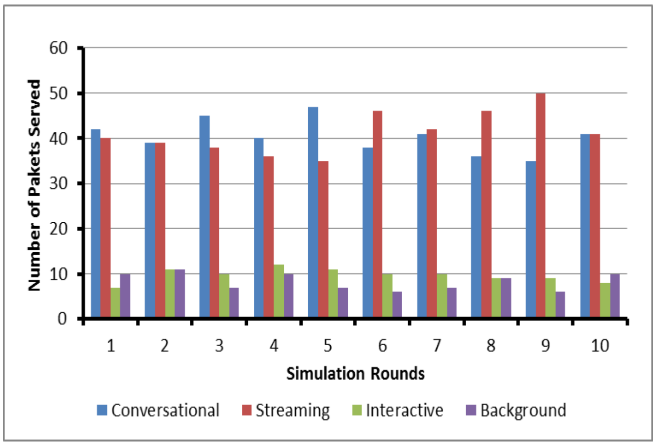

Fig. 2. Simulation Results when PQ & WRR Algorithm in use

Fig 2 shows the results of the simulation rounds with the implementation of the PQ & WRR queuing algorithm. The result shows that more of real-time traffic gets serviced while non-real-time traffic gets starved of the traffic channel, hence the very low values of interactive and background classes.

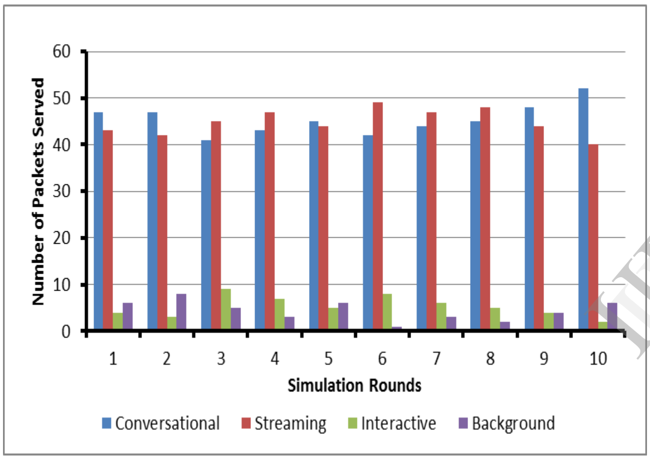

Fig. 3. Simulation Results when PQ & CBQ Algorithm is in use

Fig. 3 shows the results of the simulation runs with the implementation of the PQ & CBQ queuing algorithm. The result shows that more of real-time traffic gets served while non-real-time traffic is starved, hence the very low values of interactive and background classes also.

Fig. 4 shows the results of the simulation runs with the implementation of the developed hybrid queuing algorithm. The result shows that more of real-time traffic gets served while non-real-time traffic is not starved. A considerable amount of non-real-time traffic is served during each simulation round.

Fig. 5 shows the comparison of results for the simulation rounds. It can be seen that the hybrid algorithm gives a better performance compared to the results of the other algorithms.

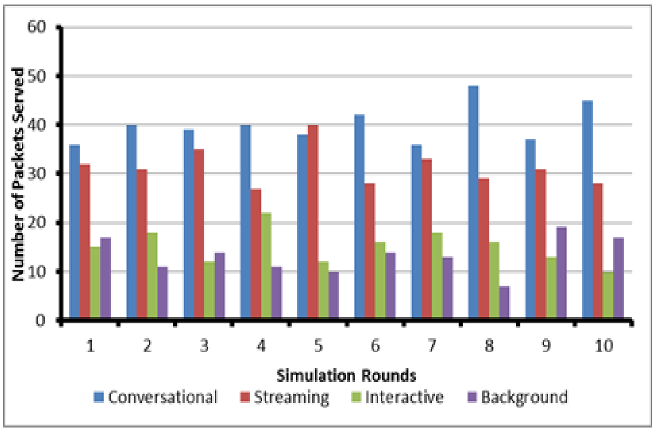

Fig. 4. Simulation Results when hybrid Algorithm is in use

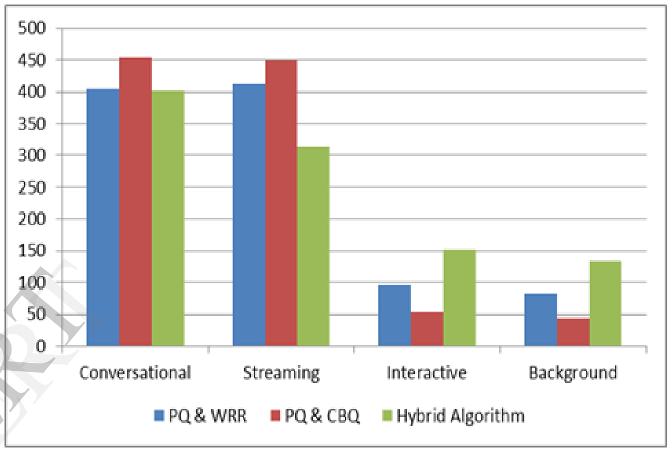

Fig. 5. Comparisons of Simulation Results in Relation with Packets Served

VII. CONCLUSION

In this research work, the problem of congestion at the access layer of the GSM network was addressed through the use of traffic class prioritization. A simplified but effective congestion management algorithm was developed. OPNET was used to study the performance of the scheme in real-world like application. The results from the simulation demonstrated that the model was successful and efficient in managing congestion. Packets from real-time traffic were admitted and served more than packets from non-real-time traffic. It was shown, via results obtained, that congestion is controlled and more importantly, traffic had been admitted and serviced, achieving optimum efficiency.

The issue of congestion management on the GSM network is very broad. Areas of recommendation for further studies include the implementation of the algorithm on the Base Station Controller (BSC) and introduction of Handoff scheme which considers the mobility of users.

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