Impact of Voice Activity Detection on Channel Allocation in Cellular Networks

Wichan Limsaksri*, Sakchai Thipchaksurat** and Ruttikorn Varakulsiripunth*

*Department of Electronics, **Department of Computer Engineering
Faculty of Engineering and Research Center for Communications and Information Technology (ReCCIT),
King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520, Thailand.
E-mail: s4061306@kmitl.ac.th , ktsakcha@kmitl.ac.th , and kvruttik@kmitl.ac.th

Abstract: In this paper, the performance enhancement algorithm of channel allocation for voice and data transmission in cellular networks is proposed. The voice activity detection has been applied to dynamic channel allocation procedure to detect and separate the silence and speech among conversation periods. Hence a data user can use the silent period of an active voice channel to transmit its information. To control the selecting of channel allocation policies, the information of number of data in transmission waiting queue has been determined in order to accept the performance measurement. In the simulation results, the improvement of the performance shows via the quality of services, which are an average delay in queue, a blocking probability, and an impact of the proposed scheme is presented in the system.

Keywords: Channel Allocation, Voice Activity Detection, Cellular Networks, TDMA

1. INTRODUCTION

In the next generation of mobile communication in cellular networks, the efficient utilization of the available resources, especially the spectrum resource, is a primary objective. However, the time-division multiple- access (TDMA) that used in mobile systems provide voice service with tolerable blocking probabilities as about 1%-3%. Consequently, this will leave the traffic channels (TCHs) idle even during the busy hours. To efficiently organize the spectrum resource, the idle TCHs may be utilized by packet-switched data services. Such as in general packet radio service (GPRS), which was defined by the European Telecommunications Standards Institute in 1994, permits the data terminals to share the idle voice channels in global system for mobile (GSM) communications to transmit its data.

A conversational speech in mobile communication can be considered as a variable data rate source made up of speech (or talkspurts) and silent periods by voice activity detection (VAD). A voice user will take more or less 50% of the time on average in speaking (speech period) and the remaining time pausing or listening (silent period). Therefore, one solution in order to fulfil the channel efficiency is to utilize the silent periods of active voice channels to transmit data of messages [1]. However, the risk of data and voice corruption can be happened. The term of "data" used in this paper means any transmitted information or message except voice.

Different from the previous works, this paper will focus and discuss on the impact of VAD algorithm by comparing our proposed algorithm with the current or conventional channel allocation. The simulation is perfformed in order to investigate this impact and also to show the performance comparison in term of voice and data blocking probabilities, data transmission delay.

2. VOICE ACTIVITY DETECTION

Voice Activity Detection (VAD) is a mechanism that can distinguish between speech added with background noise and background noise only. The input signal may be speech signal under high noise levels. The output from the VAD is then a signal that possesses the information whether the input signal contains speech (e.g. output signal value 1) or only noise (e.g. output signal value 0). For easier computation, the input signal is divided into frames, and the speech/noise decision is done only once for every frame. Within one frame, the speech signal (and also the noise signal) is supposed to be stationary; this assumption allows applying conventional techniques of signal processing to this problem. The reasons why voice activity detection is useful depend on the application. If one wants to store recorded speech signals, the amount of storage capacity can be reduced since the known noise passages do not need to be saved. In the same way, the required capacity of a speech transmission channel can be reduced, if only the speech parts of a recorded signal are transmitted. In very noisy environments, noise suppression is needed before further speech processing can take place. The VAD sorts out the data without speech, so that the noise suppressor can use this data to estimate the noise statistics. For instance, discontinuous transmission (DTX) has been developed for a mobile communication system. The goal is to reduce power consumption and to reduce the interference in a cell. During a normal conversation, the participants speak only 50% of time, i.e., each direction of transmission is occupied about 50% of time. DTX is a mode of operation where the transmitters are switched on only for those frames containing useful information. The difficulty is to find techniques to distinguish noisy speech from real noise even in a noisy environment. These algorithms are implemented in the VAD function. The background noise has to be evaluated in order to transmit characteristic parameters to the receiver side. The receiver side generates a similar noise called comfort noise during the periods that the radio transmission is cut.

In this paper, the application of the VAD in the work is implemented for general cellular systems. Furthermore, the VAD has been applied with dynamic channel allocation in order to increase available traffic channel for data transmission while considering the impact on quality of service for voice.

3. SYSTEM MODEL

Considering TDMA as a cellular system, this includes a base station (BS), a number of voice terminals (VTs) and a number of data terminals (DTs) in one particular cell. The model of cellular system is shown in Fig.1. By the assumption that the activities occurred in any cell in a cellular system are similarly, then only a homogenous cell has been considered in this paper, where voice from VTs and data from DTs are taken into account. Voice provision depends on usual circuit-base oriented. At the same time, data packets are relied on packet-base oriented, using the same resources deployed for voice connection. We assume that all the arrivals of the service requests from voice and data users are independent, and data packets are transmitted under an error-free environment unless they collide with voice transmission which adopts the voice priority channel allocation policies.

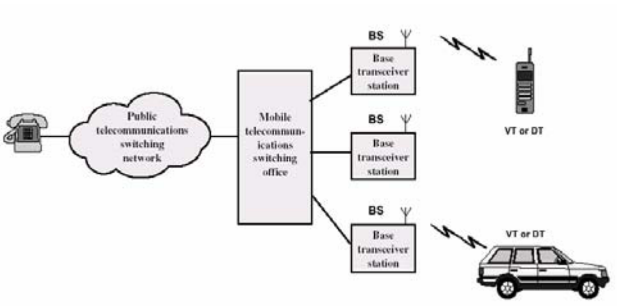

Fig. 1 The model of cellular system.

Since the duration of a data transfer is typically much smaller than the time spent by a user in a cell, we neglect the possibility that a user requests a handover procedure while transferring data.

In this system, we refer that conversation period is a random sequence of consecutive segments of speech and silence [2]. And VAD is employed in VT to detect and separate a conversation period into speech and silence. An active VT will not transmit any signal during its silent periods. Meanwhile an active DT will be placed into a first-come first-served (FCFS) queue if they can contain data packets within a buffer size. By doing this, it is allowed to transmit data packets only in the specified slots when the status of the channel is idle. That means this time slot has not been assigned to the VTs or we will use the time slots of an active channel while the status of the channel is silence. We focus on the voice (or call) blocking probability caused by the lacking of idle channel to assign a slot for its new request. We also focus on main QoS parameters for the data transfer service, such as the data blocking probability and the average delay in queue. Rejection of data transmission is caused by two possible reasons: blocking due to a full occupied queuing buffer and unavailability of resources due to preempted voice. To lower the harmful effect on the voice services, we assign full priority to voice transmissions. This means that data services will be preempted by voice requests. Finally, the simulation model of the cellular system mentioned above can be represented as shown in Fig. 2.

4. ALGORITHM and SIMULATION

As we have mentioned before that it will be flexible and convenient if data channels are assigned by the basis of the actual data traffic load. That is why our proposed algorithm will use the information of queue length to reserve transmission channel for data. Not only dynamically reserved channels but also silent periods in each conversation will be used to transfer data packets. In fact, the rising of voice connection has led to the proportionally increasing of silent periods, resulting in the increasing number of data packets that can be transmitted over that channel. Like the previous work [3], the information about queue length will be used by the acceptance on the number of voice corrupted in the system. From the simulation model in Fig. 2, the arrival process or the occurring events of voice and data in the system can be sketched as shown in Fig.3.

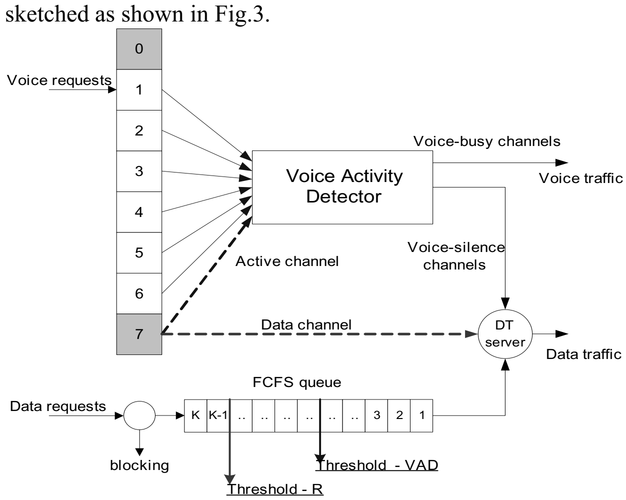

Fig. 2 The simulation model of a cellular system.

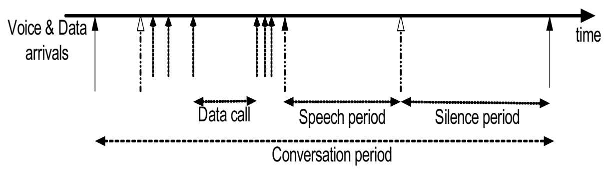

Fig. 3 Model of traffic connection (voice & data session).

Here, the procedure of conventional channel allocation for data service is shown in Fig. 4, where the data flow is similar as mentioned above. And the procedure of proposed channel allocation is shown in Fig. 5 as a partial algorithm of Fig.4 by replacing the dashed box part. When the data request is not granted by the system, it will be placed in the FCFS queue and number in queue will be increased one level. For this reason, the appropriated policy has been invoked, following by the threshold. For instance, if the number in queue is more than *Th-VAD* (threshold for *dynamic reservation with VAD*) [3] but less than *Th-R* (threshold for *dynamic reservation*), the DT will be arranged to attach a voice-traffic channel and waits for silent period to transmit its packets. In other case, if the queue length is more than *Th-R* one of the traffic channels will be permanently assigned to DT as long as the condition is defined. The reason why we determine the threshold of VAD is that when a voice user and a data connection made a transaction simultaneously, both of them would be lost. This is our proposal to decrease voice and data corruption by using adaptive threshold.

As is normally done when modelling cellular network systems, we consider one cell at a time, and we neglect the impact of signalling. Moreover, in order to proceed the simulation model of the system, we introduce the following assumptions and notations.

The sequence of new voice requests follows a Poisson process with rate λ, and the duration that a voice request will hold the channel is an exponentially distributed random variable with mean $1/\mu$. The speech period and the silent period are both exponentially distributed with mean $1/\lambda_V$ and $1/\sigma_V$, respectively. The arrivals of newly generated and retransmitted data requests follow a Poisson process with average rate λ_D (number of data arrivals per second). The length of a data message is assumed to be geometrically distributed with mean $1/\mu_D$ blocks or frames. It can be used for the performance comparison between the proposed algorithms. In addition, this traffic model is believed to represent short-message service very well in a mobile cellular system. The period of a block is $r = 4r_f$, where $r_f = 4.615$ ms is the frame period. The maximum allowable number of data request in the system is B, which is the size of the FCFS queue. The values for some parameters used in the simulation are shown in Table 1.

Table 1 Basic parameter

Parameter	Value
No. of traffic channels in the cell, N	7
No. of channels reserved to data	1
$1/\mu$	180s
$1/\lambda_V$	1.35s
$1/\sigma v$	1s
Buffer size , B	100

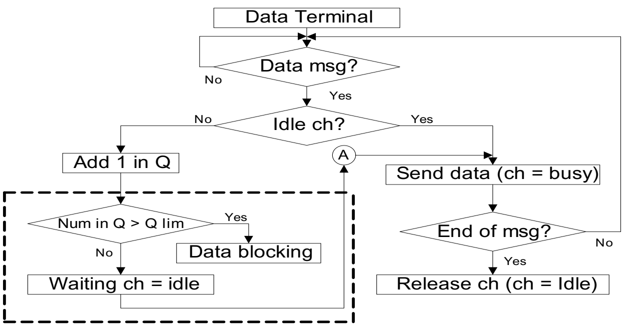

Fig. 4 The procedure of conventional channel allocation.

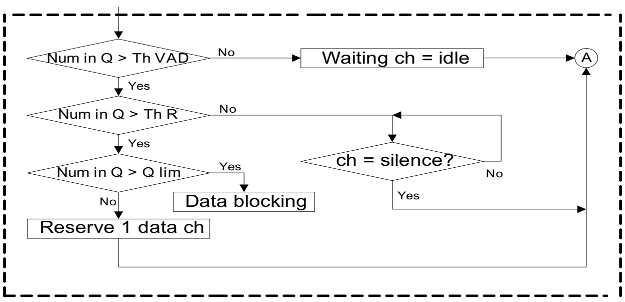

Fig. 5 The partial procedure of the proposed channel allocation.

5. SIMULATION RESULTS

In the simulation model, we assumed that there is one carrier (eight channels) assigned to a cell. Thus, one channel for signaling, and there are seven channels that can be served as a traffic channel for voice and data services. We have selected the voice traffic load (λ) as the Erlang value equal to λ/μ. Therefore, for pure voice system with N = 7, we require 2% of blocking probability, then this will be satisfied when voice traffic load = 2.95 Erlang [1].

In our results, we present the assessment of their relative merit of the different schemes, concentrating on the performance measurement of the cellular network. Figs. 6-8 illustrate the performance measurements an average delay, an average number in queue, and data blocking probability as a function of data arrival rate λ_D and average data message length $1/\mu_D$, respectively. The dashed curves represent the performance measurements of the system without using the silent periods of traffic channels to transmit data packets. In these figures, it is clear that the performance measurements of the proposed algorithm, which utilizes the silent periods of traffic channels for data service, are always better than those of the current channel allocation, as expected. From the results, we can get about 25% less average delay in queue and 20% less data blocking probability (no considering the retransmission delay) for $1/\mu_D = 5$ at heavy data traffic load.

Further investigation, Fig 9 shows the voice blocking probability. Definitely, any improvement of QoS provided in data services must be paid by voice QoS; however, surprisingly, the voice blocking probability of the proposed scheme are quite equal to the current channel allocation (marked the triangle). In the fact that, this situation results from no contention of the traffic channels between voice and data users, and the proposed policy will be used merely a silent period to transfer data packets. Moreover, if we elaborately investigates the conventional channel allocation and the fashionable channel allocation (dynamic channel allocation which marked the square and circle), we have found that the voice blocking has been increased significantly because of contention of using traffic channel between voice and data services

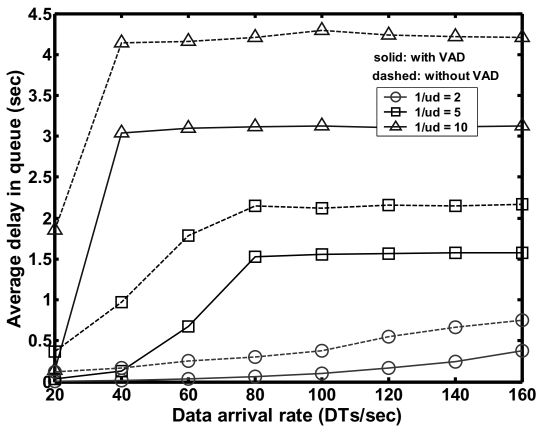

Fig. 6 Average delay in queue & data arrival rate λ_D.

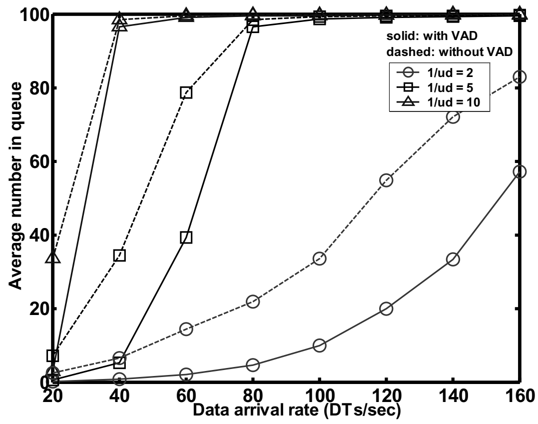

Fig. 7 Average number in queue & data arrival rate λ_D.

However, each scheme has an advantage and a disadvantage in itself. The corrupted voice will be occurred if we use the proposed scheme, and the corrupted voice will be increased if we select the small threshold-VAD. The affection of VAD technique is when data user is sending the information via a silent channel, the active voice user wants to talk again. The voice and data message will be crashed at that time. For data part, they have to be retransmitted. For voice part, maybe the listeners will perceive the message unclear for a while but it will take a short time.

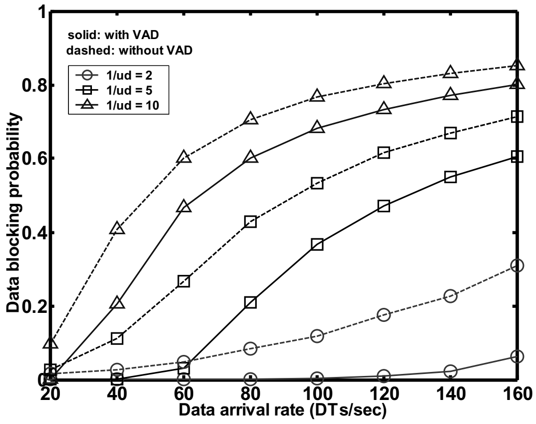

Fig. 8 Data blocking probability & data arrival rate λ_D.

If the voice signal damaged rate is not acceptable, another possible way to reduce damaged voice is as follows. Like the reservation request in packet reservation multiple access (PRMA) [4] protocols, the VT transmits two blocks of a dummy signal before it restarts voice signal transmission when it changes state from silence to speech. The BS can use this two-block duration to detect the state change and alert the corresponding DT. In this case, we will negligible voice damaged rate, but voice transmission delay is considered.

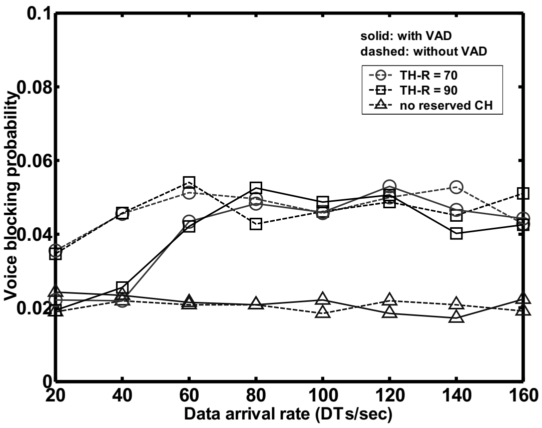

Fig. 9 Voice blocking probability & data arrival rate λ_D.

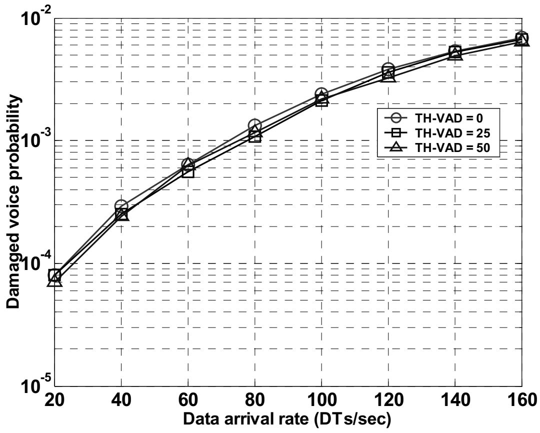

Fig. 10 Damaged voice probability & data arrival rate λ_D

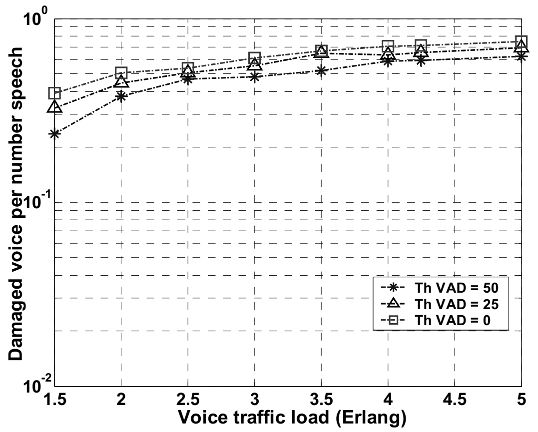

Fig. 11 Damaged voice per number speech

From Fig. 10 shows the ratio between the collision period and the total voice period. It is clear that the crashes happen too less, since the period of data services per packet take very short time when we compare the period of voice occupancy in each conversation. For Fig. 11, we fixed the data arrival rate and vary the voice traffic load instead. The figure shows the ratio of the number of damaged voice and the number of speech. It is clear to show that the crashes happen more, if we allow the data user transmitting its packet previously because of the small value of threshold VAD.

6. CONCLUSIONS

In this paper, we proposed a policy to allocate traffic channels between voice and data service in cellular networks by using voice activity detection. We have presented the method to select the policy by using information about the queue length. Whenever we use VAD scheme, it can be guaranteed that the data packet can be transmitted even when all traffic channels in a cell are busy with voice connection. The results had shown to provide very effective performance trade-off for channel usage and voice corrupted. We also show that the data service delay can be decreased by around 30-50% depending on the length of data messages. Hence, we have proposed an option to increase the channel utilization and improve the performance of delay network for data and voice system by using information of queuing buffer to handle the impact of VAD.

REFERENCES

[1] J.H. Huang, S.L. Su and J.H. Chen, "Design and Performance Analysis for Data Transmission in GSM/GPRS System with Voice Activity Detection," *IEEE transactions on vehicular technology,* Vol. 51, no. 4, July. 2002.

[2] P.T. Brady, *A technique for investigating on-off patterns of speech*, Bell Syst. Tech. J., vol. 44, no.1, pp. 1-22, Jan. 1965.

[3] W. Limsaksri, S. Thipchaksurat and R. Varakulsiripunth, "An Efficient Channel Allocation for Voice and Data with Voice Activity Detection in Cellular Networks," First ECTI Annual Conference 2004, Thailand, pp. 364-366, May 2004.

[4] S. Nanda, "Analysis of packet reservation multiple access: Voice and data integration for wireless networks," in *Proc. GLOBECOM*, 1990

[5] P. Lin and Y.B. Lin, "Channel Allocation for GPRS," *IEEE transactions on vehicular technology*, Vol. 50, no.2, March. 2001.

[6] H.H. Lin, J.L.C. Wu and W.C. Hsieh, "Delay Analysis of Integrated Voice and Data Service for GPRS," *IEEE communications letters*, Vol. 6, no. 8, August, 2002.

[7] J.W. Kim and M.S. Seo, "A Voice Activity Detection Algorithm for Wireless Communication Systems with Dynamically Varying Background Noise," *IEICE trans. Commun.,* Vol. E83-B, no. 2, February. 2000.

[8] A.M. Law and W.D. Kelton, *Simulation modeling and analysis,* McGraw-Hill, Inc., Singapore, 1982.

[9] M. Meo, M.A. Marsan, C. Batetta, "Resourec Management Policies in GPRS Wireless Internet Access System," *IEEE proceedings of the international conference on dependable systems and networks,* 2002.

[10] L. Kleinrock, *Queueing Systems,* Vol. 1., New York, Wiley, 1975.