Analysis of Blocking Probability in a GSM Based Cellular Network System

Anuj Kumar, Shilpi Srivastav, Alok Agarwal, Narendra Kumar
Email id: drnk.cse@gmail.com

Abstract— In this paper we check the performance of a GSM cellular communication system by using FDMA –TDMA system. In the present paper we evaluate the performance of the blocking probability, spectral efficiency and the bit error rate by using the a specific model. By using this we try to improve Rician and log-normal.

Keywords— GSM, Multipath effect, TDMA, North-American system.

I. INTRODUCTION

GSM System for Mobile Communications, is a standard set developed by the European Telecommunications Standards Institute (ETSI) to describe technologies for second generation (2G) digital cellular networks. GSM replaces first generation (1G) analog cellular networks by a digital, circuit switched network and expanded himself over time.

GSM networks uses radio spectrum and operates in a number of different carrier frequency ranges from 10-25MHz. Such narrow bandwidth allows 100-400 channels by dividing the whole geographical area in to small cells, and each cell may reuse the same frequencies by reducing power of transmission. Each cell has its own base station, and all base stations are interconnected using microwave or cable communication. GSM Network consists of three main parts:

- Mobile Station (MS) carried by the subscriber
- Base Station Subsystem (BSS) controls radio link with mobile station
- Network & Switching Subsystem (NSS) mobility management and switching of calls between mobile users, and between mobile and fixed network users.

As radio spectrum is very limited , GSM divides the bandwidth in 2G by using a combination of Time- and Frequency-Division Multiple Access whereas 3G uses Code Division Multiple Access (CDMA). In FDMA, the frequency spectrum is divided among the logical channels, where each user have exclusives possession of some frequency band. FDMA divides frequency bandwidth of the (maximum) 25 MHz into 124 carrier frequencies. Each Base Station (BS) is assigned one or more carrier frequencies. Using a TDMA scheme each carrier frequency is divided in time, which forms logical channels. In TDMA, users take turns in a round robin manner, where each one periodically gets the entire bandwidth for a little burst of time. Whereas in CDMA, each user is assigned a different pseudorandom binary sequence that modulates the carrier, spreading the spectrum of the waveform and giving each user a unique code pattern.

In wireless communications, the multi-path effect can cause a bit rate reduction. Multi-path effect means that a signal transmitted from a transmitter may have multiple copies traversing different paths to reach a receiver. Thus, at the receiver, the received signal should be the sum of all these multi-path signals. Because the paths traversed by these signals are different; some are longer and some are shorter. The one at the direction of light of signal (LOS) should be the shortest. These signals interact with each other. If signals are in phase, they would intensify the resultant signal otherwise, the resultant signal is weakened due to out of phase. This phenomenon is called channel fading. This is specially important in the cities, because there are many objects.

II. FDMA-TDMA CELLULAR COMMUNICATION SYSTEM

FDMA is a familiar method of allocating bandwidth where frequencies are divided up in to a particular size of channels. A transmitter in an FDMA system is given exclusive use of one or more
channels. TDMA is a more efficient, but more complicated way of using FDMA channels.

TDMA is based on dividing access time among all stations on a network and allowing each station to use the full system bandwidth and power to transmit framed bursts of data. The system has synchronized time slots, having same carrier frequency. Assume an example of generating TDMA output where A1-A4, B1-B4, and C1-C4 represent digital data from three different sources. A multiplexer (MUX) is used to combine all source data to one data stream. The multiplexing frequency FM must be fast enough so that the throughputs of the A, B, and C data are output fast enough to avoid congested and loss of data in system.

The TDMA output data stream in Fig. 1 shows the placement of the A, B, and C data in the TDMA frame. Each block represents a time slot within the frame. The time slot provides a fixed location for each group of data so at the receiver, the data can easily be recovered with the help of demultiplexer.

The arrival of the TDMA data can be an issue because of potential multipath radio frequency (RF) propagation problems with stationary systems and the added radio frequency propagation path problems introduced by mobile communications. To compensate for the variation in data arrival times, guard times are added to the TDMA frame. If the data arrive too closely together, then potential inter symbol interference (ISI) due to data overlapping can occur resulting in an increase in the bit error rate (BER). The guard times provide an additional margin of error, thereby minimizing inter symbol interference and bit errors.

In the North-American System each channel is essentially divided into three timeslots. A maximum of three transmitters take turns sending in their assigned timeslots. A conversation, then, takes place during the time slots to which each transmitter is assigned. The channel distribution is representing in fig 4.

The control channels assign a channel to a set of users, but these channels and band guards lessen the spectral efficiency. The goal of band guards is to narrow down the contiguous channel interference. In the TDMA frame used in North-American Standard, the control channels assign the voice bursts and transfer signaling information to defend the TDMA frame synchronization. This channel distribution is shown in fig 5.
According to Figures 4 and 5, the spectral efficiency in TDMA – FDMA is determined by the following equation

\[ \eta_T = \frac{\tau M_T}{T} X \frac{B_c M_a}{BW} \]  

(1)

Where:
- \( \eta_T \) Spectral efficiency
- \( \tau \) Voice burst duration, m.
- \( M_T \) Number of users in the frame
- \( T \) Total TDMA frame duration, s
- \( B_c \) Users bandwidth, Hz.
- \( M_a \) Number of user bands
- \( BW \) Total assigned bandwidth, Hz

### III. MODEL APPLIANCE (IMPLEMENTED)

Before design a model, we should consider some basic concepts of GSM network like North American QPSK \( \pi /4 \) modulation scheme, North American FDMA-TDMA standard, Rayleigh fading, Poisson distribution of service demand, first-in-first-out queues and fixed-length queues.

The channel quantity between the base station and the mobile handsets is often of poor quality because the received signals are composed of multiple reflections, often distorted through walls and other obstruction. These signals can sometimes combines out of phase, effectively cancelling each other called Rayleigh fading which can be mitigated by using a second received antenna. If the antennas are sufficiently separated in distance, then phases of the multiple signals will vary differently and infact the Rayleigh fading will be uncorrelated or independent. This means that likelihood of the signals at one antenna cancelling due to Rayleigh fading at the same time as the other receive antenna is very small. Also there is an effect of the handset motion, which cause Doppler frequency shift in the received signals and rapid changes in the inter symbol interference and fading effects requiring fast adaptive digital receives.

In American system, a form of quadrature phase shift keying (QPSK) modulation was used; called differential \( \pi /4 \) offset QPSK. It is more robust in terms of synchronization and sensitivity to Doppler shift compared to standard QPSK. It has also reduced dynamic range which is beneficial to RF power amplifier performance. The receiver in both the base station and handset were equipped with adaptive equalizers, multiple or diversity receivers, synchronization & frequency offset compensation algorithm. All of this is implemented in digital signal processing (DSP) on both the handset & base station.

(something to write about fifo & fixed length queue)

By considering all the above conditions, the main equations to consider are described in the following equations. The probability of a delay due to high demand in the Poisson process is evaluated as

\[ \mathcal{P}(t > 0) = \frac{(N)(Eb)}{N-A(1-Eb)} \]  

(2)

Where
- \( N \) Total number of available channels
- \( Eb \) Erlang-B formula
- \( A \) Offered load

If the delay is greater than the queue length then the system is blocked with probability

\[ B = P_{N+L}(A) = \frac{P_0(A)A^{N+L}}{N!N^L} \]  

(3)

Where
- \( P_0 \) Probability of high demand
- \( L \) Queue length

The probability of error is calculated by well known Marcum-Q equation and the Rayleigh fading is obtained by the combination of two Gaussian noise generators, where the line of sight (LOS) is lost in comparison with Rician fading. The Gaussian minimum shift keying (GMSK) modulation is a form of phase shift modulation. GMSK is constant amplitude type of modulation. Similar to FM, this made GSM signals very efficient to amplify for transmission in both the base station and handsets.

### IV. CONSEQUENCE

The following figure 6 shows the Rayleigh fading plots which includes time variation of the signal, histogram and signal power.

![Figure 6: Rayleigh fading](image)

Figure 7 illustrates the blocking probability for \( N=1 \), where the length of the queue is varying from 1 to 20.
Figure 8 shows the blocking probability for N=10, where the length of the queue is also varying from 1 to 20.

V. CONCLUSIONS

In this paper, the GSM cellular communication system was carried out. The structure modeled and implemented is limited to fixed-length queues. It is motivating to enhance the software presented for dynamic cases. TDMA-FDMA is very sensible to multi-path phenomenon. Now this work is being improved to consider Rician and log-normal fadings. It is important to emphasize that this kind of system presents several disadvantages which can be reduced with high bandwidth.

VI. REFERENCES

3. BER improvement in a TDMA/FDMA cellular system using antenna array by Mehrzad Biguesh, Benoit Champagne, Alex Stephemme
4. Cellular communication tutorial by Eberhard Brunner
5. Digital Signal Processing by Michael Parker
6. Distributed Intercellular Interference Management in 4th Generation TDMA TDD Cellular Mobile Wireless Communications by Pe. Omiyi, H. Haas
7. Field trial of space-time equalizer and delay diversity transmission in uplink for TDMA mobile communication by T. Toda, Y. Aihara, Jun-ichi Takada
8. Information theoretic analysis of multicell decoding and Amplify-and-Forward cooperation between mobiles for TDMA cellular systems by O.Simeone, O.Somekh, Y. Bar-Ness, U.Spagnolini
9. Mobile agent based TDMA slot assignment algorithm for wireless sensor networks by R.K Patro, B. Mohan
10. Selfconfiguration of an adaptive TDMA wireless communication protocol for teams of mobile
11. Robots by F.Santos, L. Almeida, L.S. Lopes