Modeling Traffic in an established 3G mobile Network

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ABSTRACT

Traffic models are meant to provision the increasing load of packet switched traffic in a 3G network .In this paper, we present Forward Error Correction (FEC) as a technique used for optimizing a 3G mobile network.Here, Packet Error Probability (PEP) model without Forward Error Correction, depicting the existing system and Packet Error Probability (PEP) with Forward Error Correction are simulated and their performance compared.The results are simulated and shown using the Matlab.

Keywords : Bit Error Rate, Packet Error probability, Optimization, Forward Error Correction, Signal-to-Interference Noise Ratio

1 INTRODUCTION

Today world is witnessing a radical technology transition in the field of internetworking. . This transition is evident by the convergence of the telecommunications infrastructure with that of IP data networking to provide integrated voice, video, and data services. Mobile cellular communication system is the most rapidly evolving technology in the field of telecommunication [1]. In Nigeria, there has been an extensive demand for mobile services, especially wireless internet. Recently, we have witnessed fierce competition by mobile network operators in an attempt to offer efficient quality of service (QoS) delivery to its ever growing subscribers. But given the current infrastructure, these operators face massive challenges/limitations in the course of design migration which have left them with no other option than to compromise laid down standards. One major reason contributing to these challenges is the static infrastructure/installations largely attributed to poor network planning and optimization. Though cellular network operators had 'professed' to have migrated from circuit-switched mobile technology, such as GSM, known for carrying bursty data traffic to packet switching techniques users were still not satisfied. Heavy traffic load became the order of the day as the network kept witnessing frequent hiccups such as call blocking, busy network lines, delayed traffic, cross talking, voice echoing, etc. Today we have witnessed 'friendlier' network operators whose attempt is to please its subscribers through compensations in form of night calls, free air time credit, etc. rather than a holistic overhaul of their existing infrastructure. The bottom line to this resilience is placing more interest on profit rather than optimization.

2 NETWORK OPTIMIZATION

Prior to installation of base stations, it is first necessary to perform site evaluation measurements to determine an appropriate location for the base stations. This generally consists of transmitting a Continuous Wave (CW) or unmodulated signal from a candidate site and measuring it with receiver such as the one found in a drive test system. Next, initial optimization and verification is performed to take a first-pass look at the Radio Frequency (RF) coverage when the modulated CDMA carrier is turned on. The next step is acceptance-testing phase, after which the network is handed over from the network equipment manufacturer to the wireless service provider and a sign-off process is completed. Once the wireless service provider starts commercial service, ongoing optimization and troubleshooting are continually performed during the life of the network as new cell sites are added for increased capacity or additional geographic coverage. Changes in the propagation paths continually occur, including the addition of new buildings, growth of trees, changing foliage conditions and equipment deterioration. Moreover as traffic increases, CDMA networks need to be re-optimized to account for increased level of interference caused by added traffic.

2.1 Signal to Interference and Noise Ratio (SINR)

Since channels are reused, interference arises from co-channel cells and is reffered to as intercell interference. In addition, system with non-orthogonal channelization (like non-orthogonal CDMA) must deal also with interference within the cell, called intracell interference. Particularly, in orthogonal channelization, intracell interference also arises when multipath, synchronization errors, and other practical effects compromise the orthogonality. The amount of both intercell and intracell interference experienced by a given user is captured by its SINR, and defined as;

$$\text{SINR} = P_r / N_o B + P_I \qquad (1)$$

Where: P_r is the received signal power, P_I is the received power associated with both intracell and intercell interference, and N_0B is noise power. A larger interference reduces SINR, and therefore increases user BER (Bit Error Rate). Intercell interference can be kept small by separating co-channel cells by large distance. On the other hand, the number of users in the system is maximized by reusing channel as often as possible. So the separation distance between co-channel cells should satisfy maximum channel reuse where intercell interference is kept below the maximum tolerable level for the required data rate and BER[3].

2.3 Forward Error Correction (FEC) in Cellular Network

Forward error control is a module used in wireless communication to correct errors at the receiver end. These errors must have occurred due to interference, noise or various impairments in the medium between transmitter and receiver. As the name implies, this module avoids the retransmission of the corrupted data as it helps in correcting errors at the receiver. FEC is not bandwidth efficient as it adds some amount of data as overhead at the transmitter end, but it is power efficient.

In mathematics, computer science, telecommunication and information theory, error detection and correction has great practical importance in maintaining information (data) integrity across noisy channels and less than-reliable storage media. A channel code is a broadly used term mostly referring to the Forward Error Correction (FEC) code and bit interleaving in communication and storage where the communication media or storage is viewed as a channel [4].The FEC code is used to protect data sent over the channel for storage and retrieval even in the presence of noise (errors). There exist two (2) main forms of channel codes- Convolutional codes and Block codes. Convolutional codes are often used to improve the performance of digital radio, mobile phones, satellites links and blue tooth implementations.Unlike Block encoders, convolutional encoders are not memoryless devices. A Convolutional encoder accepts a fixed number of message symbols and produces a fixed number of code symbols, but its computations depend on the current set of input symbol and on some of the previous input symbols[5].

3 MODEL DESIGN

We aim at optimizing the wireless channel parameters of the existing system to meet with the expected Qos. The reason for the poor quality of service experienced by most cellular network operators could be as a result of lack of proper network optimization and management. Some network operators do not control errors in packet transmission, thus increasing the rate of data corruption in the network, which ultimately multiplies the degree of deterioration.

We propose a model that optimizes the channel parameters and guarantees maximum throughput of transmissions in the system. The wireless channel parameters determine the Bit Transmission Rate B, and the Probability of Packet Error P_e.
We consider the case of Block Codes with Forward Error Correction (FEC). Here, the numbers of bits per packet are encoded into N bits and $N \geq P_L$. Where: P_l is the Packet Length. The ratio $\rho = P_L / N$ is called the Coding Rate, since we regard the throughput in terms of conveyed information, the bit transmission capacity is
$B_r = \varrho / G d_c$ (2)
Where; G is the processing Gain
d_e represents the Chip Duration
The collection of N bits is called a Codeword, and there exist a Codeword for each of the 2^L possible bit pattern per packet. In general, the N codeword bits contain redundancy, which enables the possible recovery of the bit pattern of the original encoded packet at the receiver. We assume that up to t errors can be corrected, and that t+1 or more bit transmission errors result in a packet loss. With these assumptions, the probability of packet errors becomes:

$$P_e = \sum_{k=t+1}^{N} \binom{N}{k} [Q(G\gamma)]^k [1 - Q(\sqrt{G\gamma})]^{N-k} \tag{3}$$

Where: $Q(.)$ is defined as the CDF (Cumulative Density Function) of the zero mean unit variance Gaussian density, i.e.:

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^\infty e^{-x^2/2} dx \tag{4}$$

Now, if $\alpha = (t+1)/N$, P_e can be estimated by

$$P_e \cong 2^{N[h(\alpha) + \alpha \log_2(q) + (1-\alpha)\log_2(1-q)]} \tag{5}$$

Where:

$$q = Q(\sqrt{G\gamma})$$

h=-x $\log_2$ (x) –(1-x) $\log_2$ (1-x), is the Binary Entropy function. To determine t, or α, we use the Gilbert-Varshamov bound [10] [11], which states that for a given coding rate ρ, there exists a block code with error correction capability α, where α satisfies

$\rho = 1 - h(2\alpha)$ (6)

(5) is the proposed (optimised) packet error probability model. Now, without FEC, the probability of packet error is [12], [5]

$$P_e = 1 - (1 - Q(\sqrt{G\gamma}))^L \tag{7}$$

And it depicts the probability of packet error for the existing system. We shall simulate the Packet Error Probabilities of both systems (with and without FEC) and compare their performance in next section of this paper.
The Uplink throughput of user i, normalized by the system bandwidth, in a CDMA network is given as [13]:

$$T_i = \frac{R_i}{W}(1 - f(SIR_i))^L \tag{8}$$

Where:
Ri is the Bit Error Rate (BER) of user i
W is the System Bandwidth
L is the Packet Length
$f(SIRi)$ is the BER as a function of SIR of user i
The function $f(.)$ however, depends on the modulation scheme employed.

To assess the performance of the existing system, we compute the system's Packet Error Probability (on the average), by modifying the equal gain diversity equation in [14]. Since traffic intensity is directly proportional to the SINR, we can approximate P_e as:

$$P_e = \frac{1}{2}\left(1 - \sqrt{\frac{\rho}{2+\rho}}\right) \tag{9}$$

Where: ρ is the Traffic Intensity. Thus, substituting traffic intensity of the existing system into (9), we obtain:

$$P_e = \frac{1}{2}\left(1 - \sqrt{\frac{12.75}{2+12.75}}\right) = \frac{1}{2}(1 - 0.9297) = 0.03515 \qquad (10)$$

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4 RESULTS AND DISCUSSION

The proposed model is implemented using the Matlab. The aim is to explore as much as possible, an optimized way of of improving the current methods and operations of the existing system.We implement the proposed model and discuss the results of the simulation.

4.1 Simulation Input

The proposed models were simulated using sample data. Three sets of data were collected, with some of the parameters obtained under ideal conditions. Other parameters were continuously fine-tuned through extensive computer simulation, until we achieved a satisfactory result. Table 1, shows the sample input used for the simulation.

Table 1: Simulation Input Parameters and their Values

Simulation of Packet Error Probability (with and without FEC:	
Total bits (N)	2, 4, 6, 8
SINR (γ)	0.2-2
Processing gain (G)	24

4.1 Discussion of Results

Fig. 1 shows the effect of SINR on Packet Error Probabilty (PEP), with fixed number of bits, for systems without Forward Error Control (FEC). We observed from this (classical) approach that more packet errors occur as the packet size increases. In Fig. 2, the presence of FEC efficiently drops the PEP as N increases, indicating the benefits of transmitting more packet bits at a time (per frame). Hence, the high PEP for systems without FEC causes more transmission errors in the network, compared to systems with FEC. As can be seen, Fig. 1 is far from the realistic values, and proves the notion that the classical approach leads to overestimation of the systems parameters. Also, the same model presents a tighter bound, which ironically turns out to be a good estimation reference for network operators, as network operators always underestimate the system's performance, thus resulting in poor quality of service (Qos) delivery.

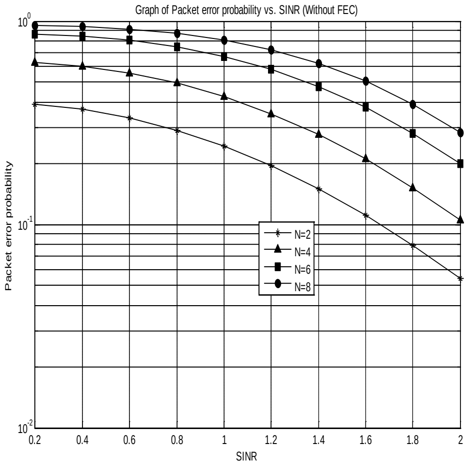

Fig. 1: Graph of Packet Error Probability vs. SINR (without FEC)

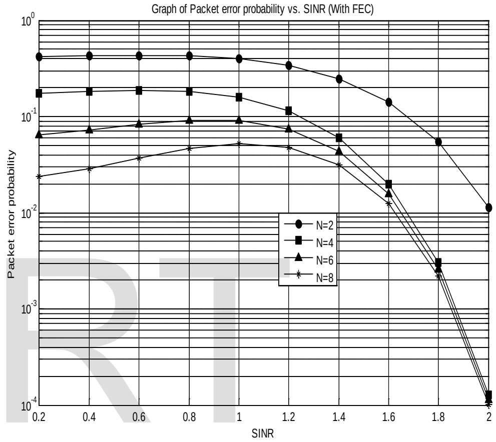

Fig. 2: Graph of Packet Error Probability vs. SINR (with FEC)

5 CONCLUSION

Forward Error Control (FEC) can be used to optimize a 3G cellular wireless network by controlling errors in packet transmission. The result has shown that, the presence of FEC is capable of efficiently dropping the packect error probability as the total number of packet bits increases, indicating the benefit of transmitting more packet bits at atime.

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