Performance Comparison of Prediction Techniques for 3G Cellular Traffic

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Abstract
Reducing the energy consumption of the cellular networks is not only a matter of interest to the network operators, but also important to the environment because the increase in energy consumption of the cellular networks will result in the increase in fuel usage which will further add the CO_2 emissions to the environment. In this paper, the dynamic operation of the cellular network is discussed. For dynamic operation of the cellular network, it is necessary to first estimate the cellular traffic. The future cellular traffic is estimated using the single exponential smoothing model and Fractionally Integrated Auto-regressive Moving Average (FARIMA). The data used for performance analysis of the single exponential smoothing model and FARIMA is of 3G cellular system in Pakistan.

Key words: Cell zooming, single exponential smoothing model, mean absolute error.

1. Introduction

In the last few decades, a lot of increase in the mobile data traffic has been observed (illustrated in Fig. 1) [1]. Along with this, the number of devices accessing the cellular network suffered from significant increase. The introduction of social networking sites such as Facebook and Twitter has further added to the mobile data traffic [2]. Therefore, the cellular network operators are paying attention to reducing the operating cost of the network. According to statistics, the information and communication technology (ICT) infrastructure counts for 2% of total CO_2 emissions across the globe in which major contribution is added by the telecommunication industry [3]. Therefore, it is clear that reducing the operating cost of the cellular network is not only of interest to the network operators, but also important to the environment.

In a typical cellular network, most of the energy (such as 60-85%) is utilized by the BSs within a radio access network illustrated in Fig. 2 [3], therefore, minimizing the energy consumption of a BS is an attractive research area. On the other hand, there are significant spatial and temporal variations in cellular traffic [4] and the cellular system is designed using the philosophy of worst case traffic (such as to fulfill the quality of service (QoS) in

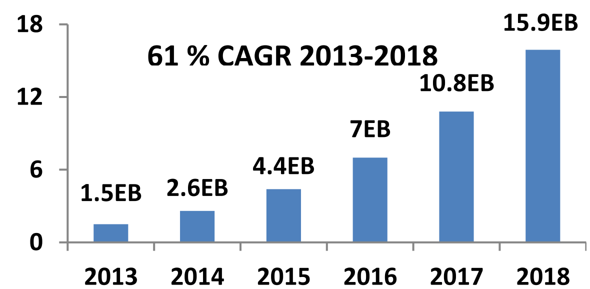

Fig. 1: Global Mobile data traffic [1]

case of a peak traffic). Therefore, there is an opportunity for the network operators to reduce the energy consumption of the cellular network by switching off some of the BSs during the period of low traffic.

Cell zooming (shown in Fig. 3) is a concept that adaptively adjusts the cell size according to the network load [4][5]. Cell zooming can be achieved using (a) coordinated operation of the cellular networks (b) physical adjustment of the antenna and (c) relaying. Although cell zooming is a promising technique for energy efficient operation of the cellular network; however its implementation might suffer from challenges. For example, cell zooming using physical adjustment of the antenna requires mechanical techniques to change the antenna tilt. Development of the algorithm to change the antenna tilt is a challenging task. Along with this, compatibility is another challenge that must be addressed. For example, the cell zooming might not be supported by the cellular system. The different energy efficient BS switching topologies were presented by Han *et al* in [6]. Coverage extension is achieved using BS coordination without loosing QoS during the period of low traffic. The closed form expressions for channel outage probability and call-blocking probabilities were also derived. In [4], Oh *et al* discussed the potential energy saving obtained using first order analysis for real time traffic along with technical challenges that arise during implementation of the dynamic operation of cellular BSs.
In this paper, the comparison of the prediction techniques for cellular traffic is performed. The future cellular traffic is predicted using single exponential smoothing model and

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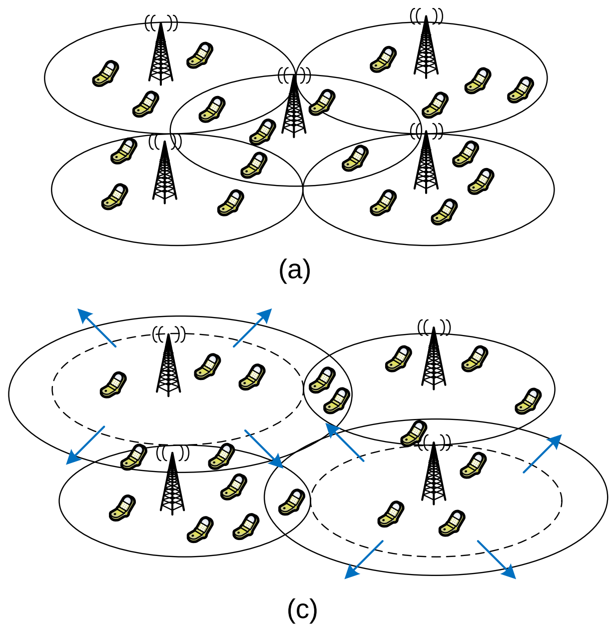

Fig. 3: (a) Cells with original size (b) Zooming in of central cell when load increases (c) central cell sleeps and neighboring cells zoom out (d) central cell sleeps and neighbor cells transmit cooperatively [5].

FARIMA. Simulation results conformed that performance of the single exponential smoothing model and FARIMA remains fine for 3G cellular traffic prediction.

The rest of the paper is organized as follows: Different prediction techniques are discussed in section 2. Simulation results are discussed in section 3 and finally, paper is concluded in section 4.

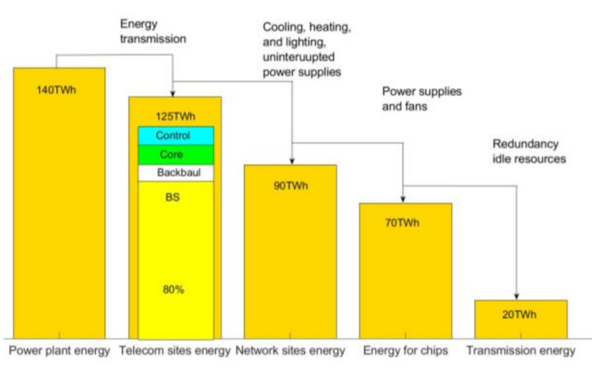

Fig. 2: Energy consumption within a radio access network[3][9]

2. Prediction Techniques for estimation of cellular traffic

Cellular traffic estimation plays an important role in network planning. In [7][8], the estimation of 3G cellular traffic was investigated. Throughput prediction in LTE was performed using exponential smoothing model and ARIMA in [7]. Estimation was done for single cell and whole region scenarios respectively. ARIMA has better performance for a whole region scenario while the exponential smoothing model has better performance for the single cell scenario. A method using both ARMA and FARIMA was proposed to predict the cellular traffic in [8]. FARIMA works effectively for the time series that shows long range dependence.

2.1 Single Exponential Smoothing Model

Exponential smoothing model utilizes early prediction and current actual value. Exponential smoothing can be secondary, cubic exponential smoothing and single exponential smoothing. Single exponential smoothing should be preferably used in case of a time series changes in unobvious manner. In this paper, we have used single exponential smoothing model. The predicted value at time $t+1$ is given by:

$$F_{t+1} = \alpha y_t + (1-\alpha)F_t \tag{1}$$

Where F_{t+1} and F_t are the currently predicted value and previous predicted value respectively. In (1), α is the smoothing constant. We have used real time data of 5 BSs of 3G cellular network located in Pakistan for one week time with one hour resolution as shown in Fig. 4.

2.1 FARIMA

The ARMA model (p,q) is given by:

$$s_t = \sum_{i=1}^{P} \Phi_i s_{t-i} - \sum_{j=0}^{q} \theta_j \varepsilon_{t-j} \tag{2}$$

Where $\theta_1, \theta_2, \ldots, \theta_q$ and $\Phi_1, \Phi_2, \ldots, \Phi_P$ are model coefficients, $s_{t-1}, s_{t-2}, \ldots, s_{t-P}$ are past data points and $\varepsilon_{t-1}, \varepsilon_{t-2}, \ldots, \varepsilon_{t-q}$ is a white noise process. ARMA model is used for stationary data, however; if the data is not stationary, then the data are made stationary by differencing operation. ARIMA is actually ARMA based on the difference time series data and the only difference between ARIMA and FARIMA lies in the degree d of differencing. The order d in case of FARIMA is taken d=H-1/2. H is the hurst parameter and its value can be computed either using R/S analysis or variance time analysis.

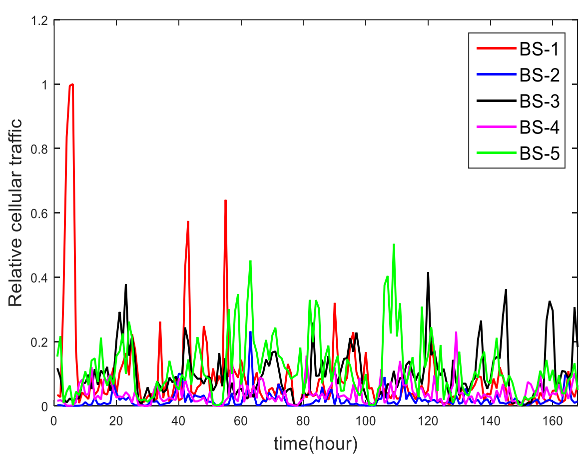

Fig. 4: Normalized cellular traffic

3. Simulation Results

This section presents the simulation results for comparing the prediction performance of the single exponential smoothing model and FARIMA. Mean Absolute Error (MAE) is used as a performance metric for single exponential smoothing model and FARIMA. MAE is given by:

$$\mathrm{MAE} = \frac{1}{N}\sum_{i=1}^{N} |f_i - y_i| \tag{3}$$

Where f_i and y_i are the predicted and actual i^{th} values for time series of length N. The data set used for analysis consist of 24 hour format. Windowing approach is used for prediction of the data. In the windowing technique, a set of inputs (lets say 6) were considered as the initial inputs. The FARIMA model can be identified using Akaike Information Criterion (AIC) criteria [8]. Table. 1 list MAE of different prediction techniques. The MAE error for real time data for a single exponential smoothing model is 0.0607 for $\alpha = 0.60$ and 0.0866 for FARIMA (4,d,4) respectively.

Table 1. MAE Performance Comparison of the prediction techniques

Technique	**MAE**
Single exponential smoothing model for α=0.60	0.0607
FARIMA (4,d,4)	0.0866

4. Conclusions & Future work

In this paper, dynamic operation of the cellular network is discussed. A comparison between the single exponential smoothing model and FARIMA is made for real time 3G cellular data. Single exponential smoothing model outperformed FARIMA. Along with this, the concept of cell zooming is also discussed.

As a future work, the framework for dynamic operation of the cellular networks can be proposed using real time cellular traffic data.

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