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A load management scheme in wireless cellular networks

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Abstract- Long-Term Evolution Advanced (LTE-Advanced) based cellular networks lead new network paradigm mechanisms. In this paper, we consider a load management scheme in wireless networks. The Discontinuous Reception (DRX) operation, each operation time slot provides appropriate network service to deliver service information. We also consider Markov chain to provide analysis frame for the network management.

Keywords- Wireless cellular networks, Load management, Long-Term Evolution Advanced (LTE-Advanced) and Markov chain.

1. Introduction

In several decades, wireless cellular network techniques are dramatically developed for the wireless network services [1-5]. And, there are additional request to satisfy explosive network service. The multimedia services needs diverse the network architectures. In the traffic management, allocated resource slot to each network service can be provided by the load management scheme [6-8].

In this paper, we consider the load management to the Long-Term Evolution Advanced (LTE-Advanced) based cellular networks [9-16]. To manage network load, we study the time slot to the network resources. Also, we consider the Markov chain mechanism for the load management.

The remainder of this paper is organized as follows: In section, we describe the Markov scheme for the load management. And, the conclusions are given in section 3.

2. Load Management

In the inter arrival time distribution function $F'(x)$, the exponential of the matrix $e^{(Q-\Lambda)x}$ can be represented by the *Cayley-Hamilton Theorem* [13]:

$$e^{(Q-\Lambda)x} = \sum_{k=0}^{n-1} \varepsilon_k (Q-\Lambda)^k \qquad (1)$$

where the n is the degree, and the $\varepsilon_k (k=0,1,\ldots,n-1)$ are determined from the set of equations driven by the eigenvalues of $(Q-\Lambda)$ as follows

$$e^{u_i x} = \sum_{k=0}^{n-1} \varepsilon_k u_i^k \cdot \qquad (2)$$

Here, the $u_i (i=1,2,\ldots,n)$ are the eigenvalues of $(Q-\Lambda)$, and can be derived by as follows

$$\Delta(x) = \det(vI-(Q-\Lambda)) = \begin{vmatrix} x+w_1 & -\beta_1 & -\frac{\beta\alpha_2}{\vartheta_+} & -\frac{\beta\beta_2}{\vartheta_+} \\ \alpha_1 & x+w_2 & -\frac{\beta\alpha_2}{\vartheta_+} & -\frac{\beta\beta_2}{\vartheta_+} \\ -\frac{\alpha\alpha_1}{\vartheta_*} & -\frac{\alpha\beta_1}{\vartheta_*} & x+w_3 & -\beta_2 \\ -\frac{\alpha\alpha_1}{\vartheta_*} & -\frac{\alpha\beta_1}{\vartheta_*} & -\alpha_2 & x+w_4 \end{vmatrix} \qquad (3)$$

where $\lambda_{\alpha*}$ and $\lambda_{\beta*}$ denote the arrival rates of normal data and retransmission data to origin data traffic. $w_1 = \lambda_{\alpha*} + \beta + \beta_1$, $w_2 = \lambda_{\beta*} + \beta + \alpha_1$, $w_3 = \lambda_{\alpha+} + \alpha + \beta_2$ and $w_4 = \lambda_{\beta+} + \alpha + \alpha_2 \cdot$

Hence, for $\Delta(x) = 0$ $(x = -u_1, -u_2, -u_3\ and\ -u_4)$, the eigenvalues are

$$u_1 = \frac{\sqrt{m+2\delta} + \sqrt{m+2\delta - 4\left((m+2\delta) - \frac{h}{2\sqrt{m+2\delta}}\right)}}{2}$$

$$u_2 = \frac{\sqrt{m+2\delta} - \sqrt{m+2\delta - 4\left((m+2\delta) - \frac{h}{2\sqrt{m+2\delta}}\right)}}{2}$$

$$u_3 = \frac{-\sqrt{m+2\delta} + \sqrt{m+2\delta - 4\left((m+2\delta) - \frac{h}{2\sqrt{m+2\delta}}\right)}}{2}$$

$$u_4 = \frac{-\sqrt{m+2\delta} - \sqrt{m+2\delta - 4\left((m+2\delta) - \frac{h}{2\sqrt{m+2\delta}}\right)}}{2}$$

where $m = -\frac{3}{8}a_1^2$, $h = \frac{3a_1 b_1 - a_1^3}{8} - b_1 - c_1$ and $\delta = \sqrt[3]{\frac{-q+\sqrt{q^2+4p^3}}{2}} + \sqrt[3]{\frac{-q-\sqrt{q^2+4p^3}}{2}}$ with

$$a_1 = -(w_1 + w_2 + w_3 + w_4) \qquad (4)$$

$$b_1 = (w_1w_2 + w_1w_3 + w_1w_4 + w_2w_3 + w_2w_4 + w_3w_4) - \frac{\alpha\beta(\alpha_1\alpha_2 + \alpha_1\beta_2 + \beta_1\alpha_2 + \beta_1\beta_2)}{\vartheta_*\vartheta_+} - (\alpha_1\beta_2 + \alpha_2\beta_2) \qquad (5)$$

$$\begin{aligned} c_1 = &-(w_1w_2w_4 + w_1w_3w_4 + w_1w_2w_3 + w_2w_3w_4) \\ &+ \frac{2\alpha\beta(\alpha_1\beta_1\beta_2 + \alpha_1\beta_1\alpha_2 + \beta_1\alpha_2\beta_2 + \alpha_1\alpha_2\beta_2)}{\vartheta_*\vartheta_+} \\ &+ \frac{\alpha\beta(w_1\beta_1\beta_2 + w_1\beta_1\alpha_2 + w_2\alpha_1\alpha_2 + w_2\alpha_1\beta_2 + w_3\alpha_1\beta_2 + w_3\beta_1\beta_2 + w_4\alpha_1\alpha_2 + w_4\beta_1\alpha_2)}{\vartheta_*\vartheta_+} \\ &-(w_1\alpha_2\beta_2 + w_2\alpha_2\beta_2 + w_3\alpha_1\beta_1 + w_4\alpha_1\beta_1) \end{aligned} \tag{6}$$

$$\begin{aligned} d_1 = &-\frac{2\alpha\beta(w_1\beta_1\alpha_2\beta_2 + w_2\alpha_1\alpha_2\beta_2 + w_3\alpha_1\beta_1\beta_2 + w_4\alpha_1\beta_1\alpha_2 + 2\alpha_1\beta_1\alpha_2\beta_2)}{\vartheta_*\vartheta_+} \\ &-\frac{\alpha\beta(w_1w_3\beta_1\beta_2 + w_1w_4\beta_1\alpha_2 + w_2w_3\alpha_1\beta_2 + w_2w_4\alpha_1\alpha_2)}{\vartheta_*\vartheta_+} \\ &+ w_1w_2w_3w_4 + w_1w_2\alpha_2\beta_2 + w_3w_4\alpha_1\beta_1 + \alpha_1\beta_1\alpha_2\beta_2 \end{aligned} \tag{7}$$

$$p = \frac{c_2}{3a_2} - \frac{b_2^2}{9a_2^2} \tag{8}$$

and

$$q = \frac{2b_2^3}{27a_2^3} - \frac{b_2c_2}{3a_2^2} + \frac{d_2}{a_2} \tag{9}$$

Here, $a_2 = 8$, $b_2 = 20b_1$, $c_2 = 8(2b_1^2 - d_1)$ and $d_2 = 4b_1(b_1^2 - d_1) - c_1^2$. Therefore, the equation (2) is represented by

$$e^{-u_1x} = \varepsilon_0 - \varepsilon_1u_1 + \varepsilon_2u_1^2 - \varepsilon_3u_1^3 \tag{10}$$

$$e^{-u_2x} = \varepsilon_0 - \varepsilon_1u_2 + \varepsilon_2u_2^2 - \varepsilon_3u_2^3 \tag{11}$$

$$e^{-u_3x} = \varepsilon_0 - \varepsilon_1u_3 + \varepsilon_2u_3^2 - \varepsilon_3u_3^3 \tag{12}$$

$$e^{-u_4x} = \varepsilon_0 - \varepsilon_1u_4 + \varepsilon_2u_4^2 - \varepsilon_3u_4^3 \tag{13}$$

From equations (10)-(14), $\varepsilon_k(k = 1,2,3,4)$ can be written by

$$\varepsilon_0 = \frac{\tau_1\tau_6 + \tau_3\tau_4}{\tau_3\tau_5 + \tau_2\tau_6} \tag{14}$$

$$\varepsilon_1 = \frac{\tau_1\tau_2\tau_6 + \tau_1\tau_3\tau_4}{\tau_3(\tau_3\tau_5 + \tau_2\tau_6)} - \frac{\tau_1}{\tau_3} \tag{15}$$

$$\varepsilon_2 = \frac{e^{-u_3x} - \varepsilon_0 + \varepsilon_1u_3}{u_3^2} - \frac{(e^{-u_4x} - \varepsilon_0 + \varepsilon_1u_4 - \varepsilon_2u_4^2)u_3}{u_4^3} \tag{16}$$

$$\varepsilon_3 = \frac{-e^{-u_4x} + \varepsilon_0 - \varepsilon_1u_4 + \varepsilon_2u_4^2}{u_4^3} \tag{17}$$

where

$$\tau_1 = (e^{-u_1x}u_2^2 - e^{-u_2x}u_1^2)(u_3^3u_4^2 - u_3^2u_4^3) - (e^{-u_3x}u_4^2 - e^{-u_4x}u_3^2)(u_1^3u_2^2 - u_1^2u_2^3)$$

$$\tau_2 = (u_2^2 - u_1^2)(u_3^3u_4^2 - u_4^3u_3^2) - (u_4^2 - u_3^2)(u_1^3u_2^2 - u_2^3u_1^2)$$

$$\tau_3 = (u_1u_2^2 - u_1^2u_2)(u_3^3u_4^2 - u_3^2u_4^3) - (u_3u_4^2 - u_3^2u_4)(u_1^3u_2^2 - u_1^2u_2^3)$$

$$\tau_4 = (e^{-u_1x}u_2^3 - e^{-u_2x}u_1^3)(u_3^2u_4^3 - u_3^3u_4^2) - (e^{-u_3x}u_4^3 - e^{-u_4x}u_3^3)(u_1^2u_2^3 - u_1^3u_2^2)$$

$$\tau_5 = (u_2^3 - u_1^3)(u_3^2u_4^3 - u_3^3u_4^2) - (u_4^3 - u_3^3)(u_1^2u_2^3 - u_1^3u_2^2)$$

$$\tau_6 = (u_1u_2^3 - u_1^3u_2)(u_3^2u_4^3 - u_3^2u_4^2) - (u_3u_4^3 - u_3^3u_4)(u_1^2u_2^3 - u_1^3u_2^2)$$

Then, the equation (1) can be expressed as

$$\begin{aligned} e^{(Q-\Lambda)x} &= \sum_{k=0}^{3} \varepsilon_k (Q-\Lambda)^k \\ &= \frac{\tau_1\tau_6 + \tau_3\tau_4}{\tau_3\tau_5 + \tau_2\tau_6} + \left[\frac{\tau_1\tau_2\tau_6 + \tau_1\tau_3\tau_4}{\tau_3(\tau_3\tau_5 + \tau_2\tau_6)} - \frac{\tau_1}{\tau_3}\right]\cdot(Q-\Lambda) \\ &+ \left[\frac{e^{-u_3x} - \varepsilon_0 + \varepsilon_1u_3}{u_3^2} - \frac{(e^{-u_4x} - \varepsilon_0 + \varepsilon_1u_4 - \varepsilon_2u_4^2)u_3}{u_4^3}\right]\cdot(Q-\Lambda)^2 \\ &+ \left(\frac{-e^{-u_4x} + \varepsilon_0 - \varepsilon_1u_4 + \varepsilon_2u_4^2}{u_4^3}\right)\cdot(Q-\Lambda)^3 \end{aligned} \tag{18}$$

Also, the matrix $(\Lambda - Q)^{-1}\Lambda$ $(= F(\infty))$ that the transition probability matrix of the Markov chain embedded at arrival epochs is given by

$$F(\infty) = \begin{bmatrix} w_1 & -\beta_1 & -\frac{\beta\alpha_2}{\beta_+} & -\frac{\beta\beta_2}{\beta_+} \\ -\alpha_1 & w_2 & -\frac{\beta\alpha_2}{\beta_+} & -\frac{\beta\beta_2}{\beta_+} \\ -\frac{\alpha\alpha_1}{\beta_*} & -\frac{\alpha\beta_1}{\beta_*} & w_3 & -\beta_2 \\ -\frac{\alpha\alpha_1}{\beta_*} & -\frac{\alpha\beta_1}{\beta_*} & -\alpha_2 & w_4 \end{bmatrix}^{-1} \cdot \begin{bmatrix} \lambda_{\alpha*} & 0 & 0 & 0 \\ 0 & \lambda_{\beta*} & 0 & 0 \\ 0 & 0 & \lambda_{\alpha+} & 0 \\ 0 & 0 & 0 & \lambda_{\beta+} \end{bmatrix} \tag{19}$$

4. Conclusions

The cellular networks may request more expended network services in the future. Hence, the resource management should be considered to the adaptable network architectures. In this paper, we consider the load management to the wireless networks. The wireless networks allocate the network resource to each network service. We consider the Markov mechanism to the load management in cellular networks.

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