KSII TRANSACTIONS ON INTERNET AND INFORMATION SYSTEMS VOL. 8, NO. 6, Jun. 2014
Copyright ⓒ 2014 KSII

Virtual Queue Based QoS Layered Vertical Mapping in Wireless Networks

Shu-guang Fang[1], **Ri-zhao Tang**[2], **Yu-ning Dong**[3] , **Hui Zhang**[4]
[1, 2]School of Internet of Things Technology, Wuxi Institute of Commerce
Wuxi, 214153 - China
[1, 3, 4]College of Telecommunications and Information Technology, Nanjing University of Posts and Telecommunications, Nanjing, 210003 - China
[e-mail: fshuguang@gmail.com[1], tangrizhao@wxic.edu.cn[2], dongyn@njupt.edu.cn[3], zhhjoice@126.com[4]]
*Corresponding author: Shu-guang, Fang

Received January 17, 2014; revised April 3, 2014; accepted May 5, 2014; published June 27, 2014

Abstract

Wireless communication is one of most active areas in modern communication researches, QoS (Quality of Service) assurance is very important for wireless communication systems design, especially for applications such as streaming video etc., which requires strict QoS assurance. The modern wireless networks multi-layer protocol stack structure results in QoS metrics layered and acting in cascade and QoS metrics vertical mapping between protocol layers. Based on virtual buffer between protocol layers and queuing technology, a unified layered QoS mapping framework is proposed in this paper, in which we first propose virtual queue concept, give a novelty united neighboring protocol layers QoS metric mapping framework, and analysis method based on dicerete-time Markov chain, and numerical results show that our proposed framework represents a significant improvement over previous model.

Keywords: wireless networks, QoS assurance, vertical QoS mapping, virtual buffer, queuing technology

---

This work is supported in part by National Natural Science Foundation of China (No. 60972038, NO. 611011 05, No. 61001077), Ministry of Education (China) Ph.D. Programs Foundation, China (No.20103223110001), Natural science fund for colleges and universities in Jiangsu Province, China (Researching on QoS assurance scheme constructing Compressed sensing technology), and the graduate student scientific research innovation project of Jiangsu Province, China (No.CXZZ11_0392). We express our thanks to the Editors and anonymous reviewers for their detailed comments and valuable contribution to improve our manuscript.

http://dx.doi.org/10.3837/tiis.2014.06.003

1. Introduction

Wireless communication is one of the most active areas in modern communication researches, whose QoS (Quality of Service) support is very important for wireless communication systems design, especially for applications such as streaming video etc., which require strict QoS assurance. QoS concerns with metrics of data transmitting quality in networks, defines the way in which networks deal with the description of applications requirements in support of their communication demands, and is scaled by QoS parameters including different values [1, 2, 3]. According to multi-layer structure of protocol stack, QoS metrics are different for each protocol layer, and forms the layered QoS metrics structure in modern wireless networks.

As ISO/OSI seven layers protocol stack, TCP/IP five layers protocol stack, wireless networks are composed of functional layers acting in cascade. For each protocol layer, QoS includes a set of QoS parameters, by which the communicating quality offered by this protocol layer is scaled [1], and must assure a specific quality level to the upper layer in terms of performance parameters. This action is defined vertical QoS mapping and provided through algorithms that schemes the network resources necessary to assure the requested QoS when traffic is transferred from one layer to adjacent one upper [4]. QoS vertical mapping in wireless networks have been extensively investigated in recent years. In reference [5], an end-to-end QoS vertical mapping model for assessing the performance of data services over networks with wireless access is proposed, this proposed model deals with performance degradation across protocol layers using a bottom-up strategy, starting up the physical layer and moving on up to the application layer; Technology-dependent layers and technology-independent layers are defined and modeled as a battery of buffers, and the QoS mapping between Technology-dependent layers and technology-independent layers is invested by queuing theory in reference [6]; Reference [7] proposes an ontology-based application and network mapping approach; In reference [8], authors formulate mapping an application request upon a substrate network as an Integer Linear Program(ILP), and the selected hosting node and link sets can provide not only enhanced quality-of-services(QoS), but also resilience against potential substrate link failures. However, there is no rigorous and unified layered QoS mapping modeling for every protocol layers up to now.

In reference[9], to investe the quality-of-service (QoS) performance at the data-link layer, authrors relie on an analytical framework based on a discrete-time Markov chain (DTMC) that jointly describes the statistical behavior of the arrival process, the queueing system, and the physical layer. Motived by this previous researches, a united QoS vertical mapping scheme between neighboring protocol layers is proposed in this paper, in which we first propose virtual queue concept, give a novelty united neighboring protocol layers QoS metric mapping framework, and analysis method based on dicerete-time Markov chain. To varify this method, we ananlyze the QoS parameters mapping between transport layer and network layer with the model proposed in this paper. Certainly, it is very easy to analysis QoS parameters mapping between physical layer and link layer by adjust reference [9] parameters to our proposed method.

The remainder of this paper is organized as follows. In section 2, a united vertical QoS mapping model based on queuing theory is proposed; this model is verified in section 3 by numerical examples; and section 4 concludes this paper.

2. The Layered Vertical QoS Mapping Model

In this section, the layered vertical QoS mapping model in single wireless network is discussed. We assume that time is slotted into discrete-time intervals of length Δt, such that the n-th time slot is defined as the time interval $\left[n\Delta t,(n+1)\Delta t\right]$; and assume the QoS management strategies are made at the beginning of each interval and the system's state is constant through each interval. Defining the interface between the N-th protocol layer and the N-1-th protocol layer as a virtual FIFO (First In First Out) buffer (**Fig.1**), S_B is the maximum size of the virtual buffer.

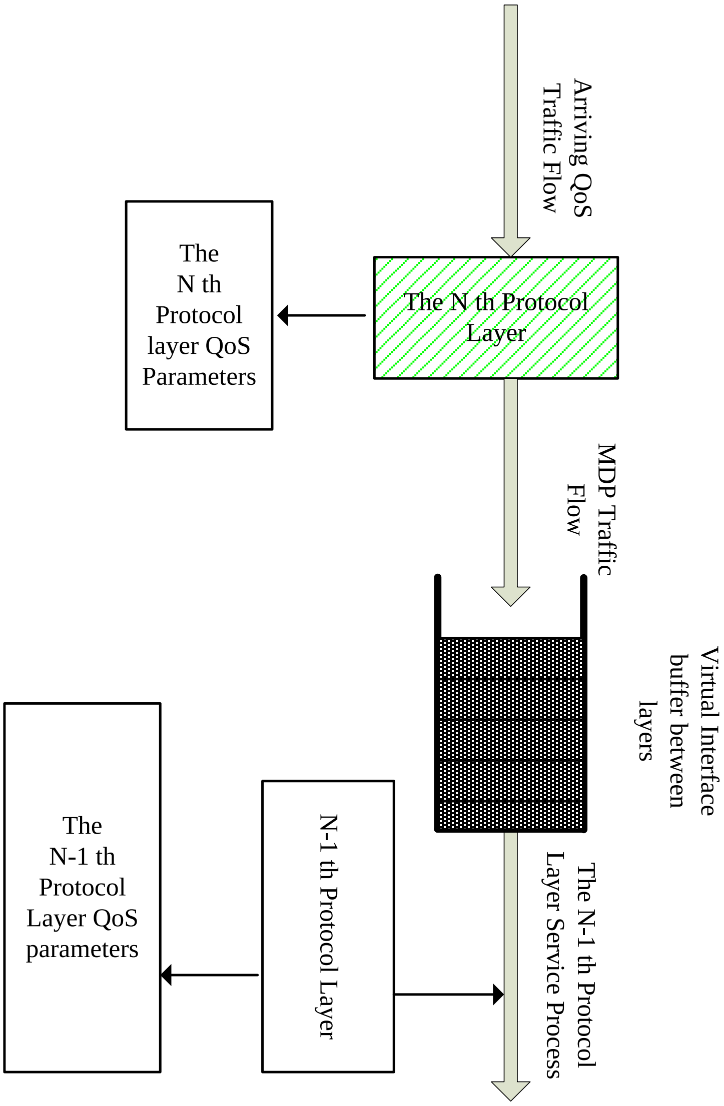


Fig. 1. The layered vertical QoS mapping model

The burstiness of traffic flow and protocoal service process is critical to assure traffic QoS[10], therefor we describe the process of traffic flow and protocoal service as Markov decision process which can be better characterize the burstiness of process, and the assured QoS parameter or protocol layer service functions consist this process decision variables. In **Fig. 1,** the QoS traffic flow, arriving to the N-th protocol layer and modeled as Markov decision process (MDP) traffic flow based on the N-th protocol layer serving, is fed into the virtual interface buffer which served by the N-1-th protocol layer Markov decision serving process. Assuming there always is sufficient QoS traffic flow in the virtual interface buffer waiting to be served by the N-1-th protocol layer, the QoS management strategy at the N-1-th protocol layer could be designed separately from the N-th protocol layer. However, this assumption is not always valid when queuing effect is taken into account in the N th protocol layer. In this part, we analyze the QoS vertical mapping based on the **Fig.1** model, considering the effect of finite-length queuing.

The N-1-th protocol layer state s_n^{N-1} is defined as the data numbers which are the packets served by the N-1 protocol layer in n-th time slot and belongs to $S^{N-1}=\left\{s_n^{N-1}: n=0,1,\cdots; N=2,\cdots,7\right\}$ **.** Assuming the protocol layer states and QoS metrics could be well estimated and are constant for each time slot, then we could model the N-1-th states sequence as Markov decision process, whose state transform probability matrix is P^{N-1} with state transition probability $p_{i,j}^{N-1}$ from state i to state j,

$$P^{N-1}=\begin{bmatrix} p_{0,0}^{N-1} & \cdots & p_{0,K}^{N-1} \\ \vdots & \ddots & \vdots \\ p_{K,0}^{N-1} & \cdots & p_{K,K}^{N-1} \end{bmatrix} \quad . \tag{1}$$

Where, P^{N-1} indicates that there exist $K+1$ states in the $N-1$-th protocol layer, and each state has itself QoS metrics, i.e., in (1), every state correspond to a QoS metrics set respectively. The stationary distribution of P^{N-1} can be defined as $\pi^{N-1}=\left\{\pi_0^{N-1},\cdots,\pi_K^{N-1}\right\}$, and computed from the following equations (2)-(3) based on the queuing theory [9],

$$\pi^{N-1}P^{N-1}=\pi^{N-1} \ , \tag{2}$$

$$\sum_{i=0}^{K}\pi_i^{N-1}=1 \quad . \tag{3}$$

Based on the stationary distribution π^{N-1} and the N-1-th protocol layer state QoS metrics, one can evaluate the QoS parameters set QoS^{N-1} in the N-1-th protocol layer, i.e., the state transition probability matrix P^{N-1} can be mapped into the QoS parameters set QoS^{N-1} in the N-1-th protocol layer, i.e.,

$$QoS^{N-1}=f^{N-1}(P^{N-1}) \ . \tag{4}$$

As **Fig.1.**, defining the interface between the N-th protocol layer and the N-1-th protocol layer as virtual FIFI buffer, which served by the N-1-th protocol layer, whose service process model is P^{N-1}, then the effect of the N-1-th layer and N-th protocol layer on traffic flow can be modeled as virtual queuing system, in which s_n^b denotes the queue state at the n-th time interval end or the n+1-th time interval beginning, i.e., the data number in queue, $s_n^b \in \{0,1,\cdots,S_B\} = S^B$. We assume the system first moves packet out of the queue at the beginning of every time interval based on service provided by the N-1-th protocol layer. Arriving data from the N-th protocol layer are placed into in the queue throughout the time interval. The arrival traffic flow process fed into the virtual buffer from the N-th protocol layer describes the number of data entering the queue at each time interval. A wide variety of traffic process is available in queuing theory literature, typically, the Markov decision process can captures the burstiness charactersistics in the traffic arrival pattern [10]. Therefore, We model the traffic flow arrive process as Markov decision process with state transition Matrix P^N.

$$P^N = \begin{bmatrix} p_{0,0}^N & \cdots & p_{0,M}^N \\ \vdots & \ddots & \vdots \\ p_{M,0}^N & \cdots & p_{M,M}^N \end{bmatrix}, \tag{5}$$

where state transition probabilities $p_{i,j}^N$ can be obtained through measurement and includes $M+1$ stationary states, $FoN = \{FoN_0, \cdots, FoN_M\}$.

After moving s_n^{N-1} data units form the virtual queue by N-1-th protocol layer service in n-th time interval, the state of virtual queue, i.e., the number of data units left in the queue are $N_n^B = \max\{0, s_{n-1}^b - s_n^{N-1}\}$, and the number of free slots in the queue at the beginning of time interval n is $F_n = S_B - N_n^B$ data units. While, the arriving data units from the n-th protocol layer is $FoN_n \in FoN$ in time interval n. If $FoN_n \le F_n$, all arrives enter the queue B and the queue state becomes $s_n^b = N_n^B + FoN_n$; if $FoN_n > F_n$, only F_n data units enter the queue, and remaining $FoN_n - S_B$ data units are dropped, and the correspondingly queue state becomes S_B. The recursion of the queue state can, therefore, be summarized as follows,

$$s_n^b = \min\left\{S_B, \max\left\{0, s_n^b - s_n^{N-1}\right\} + FON_n\right\}. \tag{6}$$

Notice that the queue state s_n^b depends on $\{s_{n-1}^b, s_n^{N-1}, FoN_n\}$, the arriving traffic flow from N-th protocol layer is independent of state pair (s_{n-1}^b, s_n^{N-1}), while s_{n-1}^b and s_n^{N-1} are closely related. To analyze the QoS metrics in the N-th protocol layer, we have to construct an Augmented Finite State Markov Chain (AFSMC) with a state pair (s_{n-1}^b, s_n^{N-1}) containing both the queue state and the N-1-th protocol layer state, named AFSMC state pair. Let $P_{(l,s),(al,as)}$ denotes the transition probability from state pair $(s_{n-1}^b = l, s_n^{N-1} = s)$ to state pair $(s_n^b = al, s_{n+1}^{N-1} = as)$, where, $(l,s) \in S^B \times S^{N-1}$, and $(al,as) \in S^B \times S^{N-1}$. We organize the AFSMC state transition probability matrix in a block form as following (7),

$$P_{AFMSC}=\begin{bmatrix} B_{0,0} & B_{0,1} & \cdots & B_{0,K} \\ B_{1,0} & B_{1,1} & \cdots & B_{1,K} \\ \vdots & \vdots & \ddots & \vdots \\ B_{K,0} & B_{K,1} & \cdots & B_{K,K} \end{bmatrix}, \tag{7}$$

where the submatrix $B_{l,al}$ is defined as

$$B_{l,al}=\begin{bmatrix} p_{(l,s_0),(al,s_0)} & \cdots & p_{(l,s_0),(al,s_N)} \\ \vdots & \ddots & \vdots \\ p_{(l,s_N),(al,s_0)} & \cdots & p_{(l,s_N),(al,s_N)} \end{bmatrix}, \tag{8}$$

where $p_{(l,s),(al,as)}$ could be obtained by similar method in reference [10],

$$p_{(l,s),(al,as)}=p_{l,al}\cdot p_{(L_t=al\mid L_{t-1}=l,s_t=s)}= \begin{cases} p_{l,al}\cdot p\left(A_t=al-\max\left(0,l-s\right)\right) & if\ 0\le al<K \\ p_{l,al}\cdot\left(1-\sum\limits_{0\le al<K}p\left(L_t=al\mid L_{t-1}=l,s_t=s\right)\right) & if\ al>K \end{cases}, \tag{9}$$

where $p_{l,al}$ can be found from the entries in P^{N-1}, $p\left(A_t=al-\max\left(0,l-s\right)\right)$ can be obtained from the stability distribution of (5), which represents the change and state of the QoS target and behaviour of the traffic. And obviously, the computional complexity in AFSMC state transition probability matrix involved (9) is $O(n)$, where, n is $\max(S^B,S^{N-1})$. Then, P_{AFMSC} obtained from (7), (8) and (9), the QoS metrics set QoS_N in the N-th protocol layer can be obtained by similar methods in reference [9, 10].

$$QoS^N=f^{N-1}(P_{AFMSC},P^{N-1},QoS^N). \tag{10}$$

Then, we have actualized the QoS metrics mapping form N-1 protocol layer to N protocol layer based on the virtual queue analysis technology.

3. Simulations

In this section, we validate the layered vertical QoS mapping model proposed in this paper for wireless Raleigh fading channel in single wireless networks with MATALAB-based simulator. It is very easy to analysis QoS parameters mapping between physical layer and link layer by adjust reference[9] parameters to our proposed method; in this section, based on TCP parameters from literature [5], our emphasis on validating this model between transport layer adopted TCP scheme and network layer. The feasibility and effectiveness of this model for other layers is one of our future works.

Assuming the state transition probabilities matrices of transport layer and network layer have been obtained by measure, the states set of network, including the length of virtual buffer between layers and throughput in network layer, is set by adjusting the consistency between simulation results obtained by model proposed in this paper and that proposed in literature [5]. We will analyze the QoS metrics mapping between transport layer and network layer through the model proposed in this paper, and which will be compared with the results of literature [5] to validate the model proposed in this paper.

Transport layer QoS metrics concerned include packet drop rate P_L, average throughput η and average delay D_p; defining $P_L = {}^{N_L}\!/_{\lambda}$, where, N_L is drop packet numbers for virtual buffer overflow, λ is the average arrive rate to virtual buffer; then defining $\eta = \lambda(1-P_L)$ and defining $D_p = {}^{\lambda}\!/_{\eta}$ (ms) for TCP scheme adopted. As for network layer QoS metrics, packet drop rate P_{net}, average throughput R_{net} and average delay D_{net} (ms) are concerned, which can be obtained by measure or simulation. Assuming P_{net} and D_{net} obtained previously, R_{net} can be obtained by the method in literature [5], and forming （P_{net}, D_{net}, R_{net}） defined as network state Net_i as in **Table 1**.

Table 1. The Network State

	Net$_1$	**Net$_2$**	**Net$_3$**	**Net$_4$**	**Net$_5$**	**Net$_6$**	**Net$_7$**	**Net$_8$**	**Net$_9$**	**Net$_{10}$**
P_{net}	0.001	0.130	0.200	0.300	0.400	0.500	0.600	0.700	0.800	0.900
D_{net}	1.200	2.300	3.500	4.200	4.600	4.700	4.900	5.000	5.100	5.300
R_{net}	3.020	4.190	3.990	4.490	4.540	3.770	2.270	1.110	0.460	0.160

Assuming the virtual buffer length $B=5$, the number of arrive packets from application layer to transport layer in unit time exists six states: $\text{ArriState}=[0\ \ 1\ \ 2\ \ 3\ \ 4\ \ 5]$, whose state transition matrix is (11).

$$P_A = \begin{bmatrix} 0.1927 & 0.0659 & 0.2264 & 0.1874 & 0.1606 & 0.1670 \\ 0.2457 & 0.1483 & 0.1316 & 0.2602 & 0.2055 & 0.0086 \\ 0.0357 & 0.2689 & 0.2248 & 0.1842 & 0.2087 & 0.0778 \\ 0.3662 & 0.3868 & 0.0569 & 0.0143 & 0.1573 & 0.0185 \\ 0.2248 & 0.0560 & 0.1499 & 0.3018 & 0.2330 & 0.0345 \\ 0.0249 & 0.2481 & 0.2341 & 0.2387 & 0.0438 & 0.2105 \end{bmatrix} \tag{11}$$

Curves in **Fig.2** show the relationship between layered mapping results for network layer packet error rate P_{net} and transport layer throughput η obtained by method in literature [5] and that proposed in this paper respectively, which indicates the results consistency, and the transport layer throughput will be reducing with the network layer packet error rate increasing, for TCP Window size reducing.

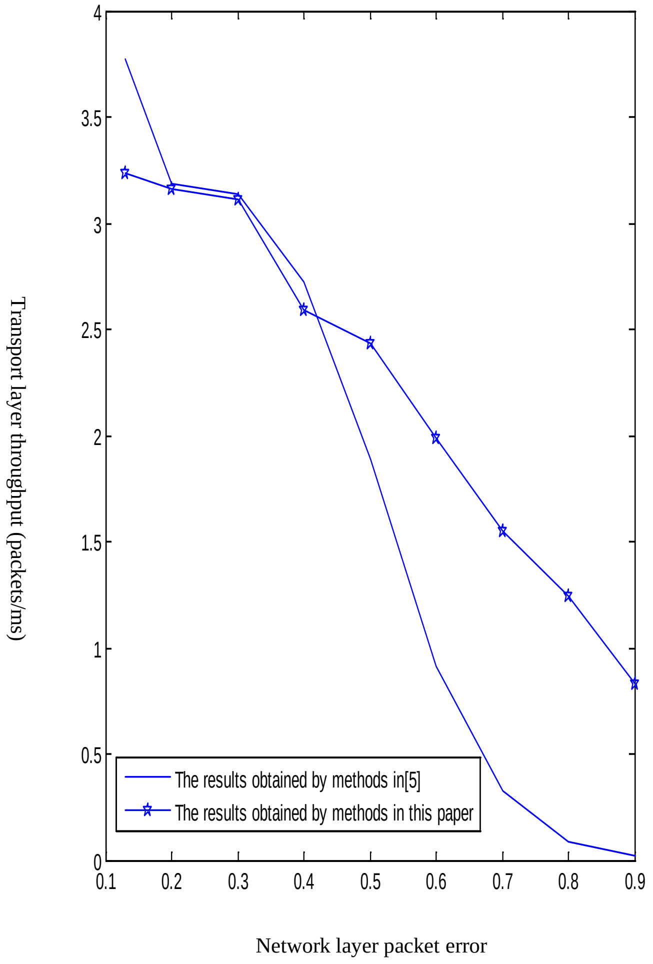


Fig. 2. The relationship between layered mapping results for network layer packet error rate and transport layer throughput obtained by method in literature [5] and that proposed in this paper respectively.

Fig. 3 shows the relationship between layered mapping results for network layer packet error rate P_{net} and transport layer delay D_p obtained by method in literature [5] and that proposed in this paper respectively. Curves in **Fig. 3** prove that the results are well consistency, and the delay D_p will be increasing with the network layer packet error rate P_{net} increasing, for TCP Window size reducing with network layer packet error rate P_{net} increasing resulting in transmitting rate decreasing.

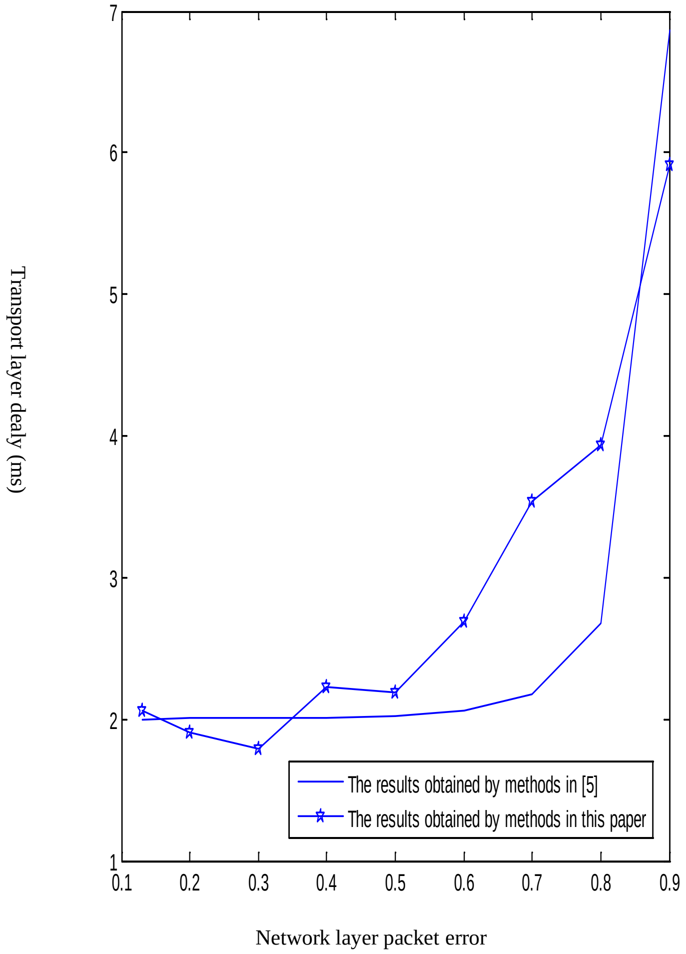


Fig. 3. The relationship between layered mapping results for network layer packet error rate and transport layer delay obtained by method in literature [5] and that proposed in this paper respectively.

The results in **Fig.3** and **Fig.4** show our propose model correctness and usability. But, for the proposed model in this paper based on virtual queue between layers, the virtual buffer length, network states and network states transition probabilty are all crtical for QoS metrics analysis, which are all set by exhaustive searching adjusting the simulation results consistency, therefor, there exist difference between curves in **Fig.3** and **Fig.4**.

Reference[5] presents an end-to-end Quality of Service (QoS) model for assessing the performance of data services over networks with wireless access, which deals with performance degradation across protocol layers using a bottom-up strategy, starting with the physical layer and moving on up to the application layer. Depending on different mathematical models in protocol layers strictly and the solution of nonlinear equation makes this model strictly depending on the concrete technology in different layer and results in different QoS mapping model for different technology adopted in protocol layers. For example, QoS metrics mapping beteen physical layer and data link layer, the different technology adopted by data link layer resutls different QoS mapping model, referred to refrence[5]; QoS metrics mapping analysis between transport layer and network layer strictly depend on the solution of nonlinear equation, the analysis formulas of transport layer throughput R_{L4} and delay D_{L4} are following (12) and (13)[5].

$$R_{L4} = \phi(f_1(S_{L3} \cdot N_u), f_2(S_{L3} \cdot N_u); W, b, T_0) \cdot (1 - P_{L3}) \qquad (12)$$

$$D_{L4} = D_{L3} + \sum_{i=0}^{\infty} (P_{L3})^i (D_{rtx} + D_{L3}) \qquad (13)$$

Where, $\phi(\cdot)$ characterize the nonlinear relation between TCP throughput and the total network load $S_{L3} \cdot N_u$, maximum TCP widows size W, the number of packets b acknowledged by each received ACK and retransmission time-out duration; P_{L3} and D_{L3} denote the loss rate and average delay in the network; D_{rtx} is the period time required by the transmitter to detect the need for a retransmission. The solution of (12) and (13) strictly depend on the model of concrete network layer and concrete TCP layer which may be highly complexity or be required using curve fitting, more details about (12) and (13) refferred to reference[5].

The superiority of the model proposed in this paper is that a unified framework for layered vertical QoS mapping, in which different protocol layer technology mapping into this queue model, is proposed.

4. Conclusion

Qos assurance is one of critical issues in modern wireless communication, especially for stream traffic. The multi-layer structure of protocol in modern wireless networks results in the layered QoS structure, in which every protocol layer provides corresponding service and special QoS parameters and acts each other to assure the traffic QoS, and which results in vertical QoS parameters mapping between protocol layers. In this paper, based on the virtual buffer between protocol layers and queuing technology, a unified protocol layer QoS parameters mapping framework is provided. To verify the feasibility and effectiveness of this framework, we compare the numerical results obtained by the model proposed in this paper and that proposed in literature [5], and analyzes the computing complexity. Numerical results show that our proposed framework represents a significant improvement over literature [5].

But for time and vigor limiting, we only analyze the QoS parameters mapping between transport layer and network layer with the model proposed in this paper, physical layer and link layer QoS mapping is obviously and simply obtained by adjusting parameters in literature [9] to the model proposed in this paper, other layers QoS mapping verifying with this model is one of our future works. And, in this paper, we assume the buffer seviced rate defined as the data numbers served by the N-1 protocol layer in n-th time slot be well estimated and are constant for each time slot, but when some QoS metrics is deployed, the rate allocation strategy applied to the buffers is one of interesting and opening topics and one of our future works.

References

[1] B. Stiller, "Hierarchical mapping of enhanced QoS parameters based on OS1 protocols," *Third IEEE Workshop on Architecture and Implementation of High Performance Communication Subsystems*, pp. 43-46, 1995. Article (CrossRef Link)

[2] L. A. DaSilva, "QoS mapping along the protocol stack: discussion and preliminary results," in *Proc. of IEEE International Conference on Communications*, vol.2, pp. 713 – 717, 2000. Article (CrossRef Link)

[3] D. Chalmers and M. Sloman, "A survey of quality of service in mobile computing environments," *IEEE communications survey & Tutorials*, vol.2, no.2, pp. 2-10, 1999. Article (CrossRef Link)

[4] F. Davoli, M. Marchese and M. Mongelli, "Bandwidth adaptation for vertical Qos mapping in protocol stacks for wireless links," in *Proc. of IEEE Global Telecommunications Conference*, pp. 1-6, 2009. Article (CrossRef Link)

[5] Gerardo Gomez, Javier Poncela Gonzalez, Mari Carmen Aguayo-Torres and Jose Tomas Entrambasaguas Munoz, "QoS modeling for end-to-end performance evaluation over networks with wireless access," *EURASIP Journal on Wireless Communications and Networking*, vol. 2010, pp.1-17, 2010. Article (CrossRef Link)

[6] Mario Marchese and Maurizio Mongelli, "Vertical QoS mapping over wireless interfaces," *IEEE wireless communications*, vol. 16, no. 2, pp. 37-43, April 2009. Article (CrossRef Link)

[7] Achilles Colombo Prudêncio1, Marcelo Luz Sheibel and Roberto Willrich, "Application and network QoS mapping using an ontology-based approach," in *Proc. of Third International Conference on Communication Theory, Reliability, and Quality of Service*, pp. 214-219, 2010. Article (CrossRef Link)

[8] Zhang Xian, C. Phillips and Chen Xiuzhong, "An overlay mapping model for achieving enhanced QoS and resilience performance," in *Proc. of 3rd International Congress on Ultra Modern Telecommunications and Control Systems and Workshops (ICUMT)*, pp. 1-7, 2011. http://www.deepdyve.com/lp/institute-of-electrical-and-electronics-engineers/an-overlay-mapping-model-for-achieving-enhanced-qos-and-resilience-1ub6pkRNnL.

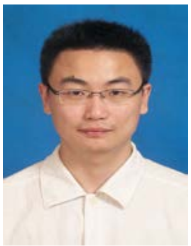
[9] Guillem Femenias, Jaume Ramis and Loren Carrasco, "Using two-dimensional Markov models and the effective-capacity approach for cross-layer design in AMC/ARQ-Based wireless networks," *IEEE transactions on vehicular technology*, vol. 58, no. 8, pp.4193-4203, OCT. 2009. Article (CrossRef Link)

[10] Liu Qingwen, Zhou Shengli and Georgios B. Giannakis, "Queuing with adaptive modulation and coding over wireless links: cross-layer analysis and design," *IEEE Transactions on wireless communications*, vol. 4, no. 3, pp.1142-1153, MAY 2005. Article (CrossRef Link)

Shu-guang Fang received his Ph.D. degree in signal and information processing from Nanjing University of Posts and Telecommunications, China, in 2013. He is currently working as a teacher in Internet of Things Department, Wuxi Institute of Commerce, Wuxi, China. His current research interests are in wireless network optimization, QoS assurance mechanism, signal processing technology in wireless networks, and electrical automation technology. (E-mail: fshuguang @gmail.com)

Ri-zhao Tang received his Master's degree in Computer Technology from Jilin University, China, in 2006. Currently, he is an associate professor in Internet of Things Department, Wuxi Institute of Commerce, Wuxi, China. His current research interests are in Computer technology and Internet of Things Technology. (E-mail:Tangrizhao@wxic.edu.cn)

Yu-ning Dong received his Ph.D degree in Engineering from Southeast University, China, in 1988, and M.Phil degree from Queens University of Belfast, U.K, in 1998. He worked as British Postdoctoral research at Imperial College University of London, U.K from 1992-1993. He has been engaged in teaching and researching on Multimedia Communications and IP networks. He is full professor now at Nanjing University of Posts and Telecommunications. His research interests include multimedia communications and wireless Mesh networks. (E-mail: dongyn@njupt.edu.cn).



Hui Zhang received his Ph.D. degree in signal and information processing from Nanjing University of Posts and Telecommunications, China, in 2008. Currently, he is an associate professor and Master supervisor in the Jiangsu Provincial Key Lab of Wireless Communications, Nanjing University of Posts and Telecommunications. His main research direction is the next generation of wireless ubiquitous network. (Email: zhhjoice@126.com.)