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A Congestion Control Scheme for LTE/SAE

Fang Cheng, Xiao-Fei Hang and Hong-Jiang Lei

Chongqing University of Posts and Telecommunications, ChongQing, 400065, China

Abstract. On the base of researching about architecture and flow characterize of LTE/SAE, focus on congestion problem on Packet Data Network Gateway caused by the busty service of next wireless communication, proposed a high level protocol congestion control scheme based on virtual queue random early drop. NS2 was carried out under the LTE/SAE simulation platform. Simulation results show that the scheme to improve throughput while reducing latency and packet loss rate.

Keywords: LTE/SAE, Congestion Control, VQ, RED, P-GW

1. Introduction

With the continuous emergence of new technologies, to maintain its mobile communications technology leadership in the next decade,3GPP found it necessary to pass through the continued evolution and enhancement from wireless interface to core network, so there starts the next generation mobile communication systems standardization.3GPP divides the standardization into LTE and SAE[1] ,which will be carried out respectively. The former is responsible for E-UTRAN, while the latter is responsible for the coordination with evolution of the wireless access network to work out the Evolved Packet Core Network, The two combine to form Evolved Packet System LTE/SAE.

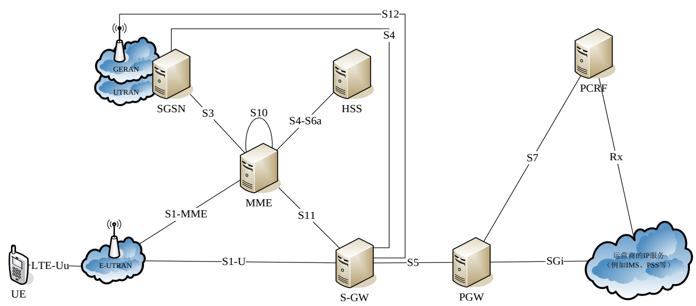

Fig.1: LTE/SAE Architecture

Figure 1 illustrates the architecture of LTE/SAE. Pre-LTE System, which contains UTRAN and GERAN, accesses to SAE by SGSN, E-UTRAN establishes connections of user plane and control plane with MME and S-GW respectively. P-GW, the gateway to connect SAE to external network, can provide PDN connection for users who access to LTE/SAE. External network can make the Internet and IMS to packet data network. With the continuous integration of networks, Non-3GPP wireless access such as EVDO、WLAN and WiMax will access to LTE/SAE, while multimedia and high-speed data services based on SIP will continue to become wide, and P-GW will be the bottleneck in the network nodes, in this case, there is need to carry on network flow control.

2. **Related work**

Congestion Control in the Internet network is divided into Congestion Control at the end system and Congestion Control at the network side. Congestion Control at the end system mainly rely on various versions of TCP [2~4] protocol, while Congestion Control at the network side is achieved by carrying on active queue management [5] in buffer queue of router, dropping packets predictably before the formation of a full queue, avoiding deadlock, full queue and global synchronization caused by packet loss, type of Drop-Tai. Active queue management mechanism can be divided into two categories. One based on real queue and the other based on virtual queue. Active queue management mechanism based on real queue contains REM[6][7]、RED[8]、PI[9] control. Based on virtual queue [10] and corresponding to real queue, queue management has a rate less than real queue. Packet drop or mark is based on whether the virtual queue is full or not. Literature [11] studied the congestion control mechanism combined by virtual queue and real queue. Through simulation, there comes the conclusion that dealing with burst data's robustness, queuing delay and jitter, active queue management mechanism based on virtual queue has the original active queue management mechanism.

Currently, active queue management technique has extended from the traditional Internet to other networks. What is mostly studied now is the WLAN based on the IEEE 802.11 standard. Literature [12] proposed that adopting active queue management mechanism contribute to solving the fairness of up/down flow, in addition, it provides higher throughput in the wireless interface. Cheng-Chih Yang etc proposed a solution to differentiate QoS priority in the WLAN by using RED technology in literature [13]. In addition to WLAN, active queue management has also been used in IP-based satellite network [14]. Currently 3GPP mobile communication network based on congestion control in the application of the main concerns in wireless access part, which Marc C etc proposed a congestion control will be introduced to the HSPDA system Iub interface is used to prevent downstream rate caused by excessive congestion at the Node B in literature[15]. Nadas S etc proposed a Iub interface to the transmission network under a limited scenario can be maintained under the low latency and low packet loss programs to enhance end user throughput in literature [16]. There are a few studies about congestion control in the aspects of core network. So far, only Filho.E.L etc pointed out that congestion problem will also appear in IMS system with the proliferation of P2P traffic in literature [17]. And they proposed improve the reliability of signaling information by using SCTP protocol in place of UDP bearing SIP signaling. But at present there is no study about the traffic control for SAE. Traffic control in SAE depended on different traffic registration. 3GPP divided traffic into four QoS classes, namely, conversation class, streaming media class, interactive class and background class. Traffic control of SAE is for services of background class, in order to get higher network utilization under the premise of no effect on the above 3 QoS classes.

Qiu adopted layered VQ-RED to improve system throughput in literature [18]. When background traffic carries on congestion control, the scheme uses three kinds of packet loss strategies: head dropped, lost tail and random drop. When dropping packets, these three schemes have no selective on which TCP flow the packet belongs to. It will cause that the packets dropped/marked is smaller cwnd TCP flow while larger cwnd TCP flow do not feel the network congestion occurred. In this case, the effect disposable lost/marking operation caused on limit traffic is very limited, and larger cwnd TCP flow views that the network congestion does not occur, and then continue to increase cwnd, which makes it easy for the virtual queue to reach the maximum length, forming queue packet loss of Drop Tail, resulting global synchronization of TCP flow. Next section will detail to solve this problem.

3. Congestion control on the P-GW node

Different from the traditional Internet which is only related to the third layer, in purpose of security and convenience for network management, P-GW contains the application layer protocol, using GTPv2 as the protocol of application layer in the scene that 3GPP accesses to LTE/SAE, and establishes PDP context and tunnel on the S5/S8 interface for every user. When data flow from external network enters into P-GW node, there will be PDP context searching, locating which user the service data packet will be sent to and through which S5/S8 the service data packet will be sent.

Here moves queue management to application layer to achieve. The implementation of the program is shown in Figure 2. Sent to application layer, lower packet firstly carries on PDP context mapping, and determines the QCI of this group, and then put groups into different queues according to different QCI. In which the first 3 classes use Drop Tail while QoS Class 3 queue uses an improved version of the VQ-RED

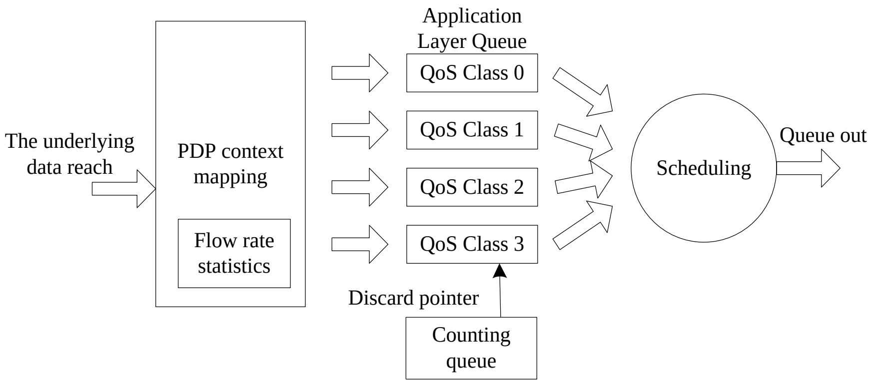

Fig.2: Application Layer Queue Management Scheme

This program will add three parameters: counting matrix of flow rate C_f 、counting queue q_c and discard pointer d_p .In which the length of flow rate counting vector is related to the number of TCP background flow, recording the rate of each TCP flow. For example, there is N background flows, then

$$C_f = \{\vec{c}_{f1}, \vec{c}_{f2}, \vec{c}_{f3}, ..., \vec{c}_{fN}\}^T \tag{1}$$

In which, $\vec{c}_{fi} = \{c_{ui}, c_{ti}\}, i = 1, 2, ..., N$. c_t represents the value being counted and c_u represents the count that can be used. What count stores are packets of interval required when two belonging to the same background flow reach queue. The smaller the value , representing the more network resources occupied by the background flow, and the larger cwnd. The next section will detail the workflow when the two values is running in the queue. Counting queue is also a vector. If there are M packets in the queue at time t, the counting queue can be expressed as

$$q_c = \{r_1, r_2, ..., r_m\} \tag{2}$$

In which, $r_i, i = 1, 2, ..., m$ is the count rate of TCP flow to which every packet in the queue belongs. Discard pointer points to the packet required when packet loss occurs, namely,

$$d_p \to \min\{r_1, r_2, ..., r_m\} \tag{3}$$

Here sign “$\to$” represents pointing. For example, $\min\{r_1, r_2, ..., r_m\} = r_n$, and then $d_p = n$.

According to packet arrival, group to leave and packet drop, the following section will explain the changes of the above three parameters when the work of VQ-RED is carried on. The operational status of virtual queue is the same to the schemes in literature [18].

3.1. packet arrival

Group of background class based on TCP protocol will firstly carry on PDP context mapping after it is handed by lower layer, finding the legitimacy of this packet and distinguish which user’s background flow the packet belongs to. Suppose packets received belong to j background flow, updating C_f according to the following formula.

$$C_f \leftarrow C_f + \{\vec{\alpha}, \vec{\beta}\} \tag{4}$$

In which, $\vec{\alpha} = (\alpha_1, \alpha_2, ..., \alpha_N)^T$ and $\alpha_k = \begin{cases} c_{tj}, & k = j \\ 0, & k \neq j \end{cases}$ (5)

while $\vec{\beta} = \{\beta_1, \beta_2, ..., \beta_N\}^T$ and

$$\beta_l = \begin{cases} -c_{tj} & l = j \\ 1 & l \neq j \end{cases} \tag{6}$$

And then update the counting queue to $q_c = \{r_1, r_2, ..., r_m, r_{m+1}\}$, in which $r_{m+1} = c_{tj}$. Determine the relationship between r_{m+1} and d_p . If $r_{m+1} > d_p$, $d_p = m+1$, otherwise the value of d_p does not change.

3.2. packet left

When packet leaves, C_f does not need to update, while q_c updates according to the following manner

$$q_c \leftarrow \{r_2, r_3, ..., r_m\} \tag{7}$$

At this time, if $d_p \neq 1$ does not need to update, otherwise it needs to re-find the value of d_p according to manner (3).

3.3. packet discard

Satisfying the packet loss conditions, the d_p packet is to be dropped, and q_c is updated to

$$q_c = \{r_1, r_2, ..., r_{d_p - 1}, r_{d_p + 1}, ..., r_m\} \tag{8}$$

The update of the value of d_p is the same with packet left.

4. Performance Evaluation

4.1. The Environment of Evaluation

Here we choose NS2 simulation environment to evaluate the LTE/SAE model. Nodes configuration in the network is shown in Table 1.

Table 1. Node Configure in Network

Node id	numbers of nodes	Node class	Explanation
0	1	FTP Server	FTP services available
1	1	HTTP Server	HTTP services available
2	1	Stream Server	Streaming media services available
3	1	SIP Server	SIP session services available
4	1	P-GW	Packet data gateway, providing downlink congestion control
5	1	S-GW	Access gateway in SAE
6	1	eNB	Evolved Node B
7~n	n-6	UE	Terminal, initiate services

In the simulation, services contained in every UE, including:

(1) SIP session services, 64kbps two-way connection between UE and SIP Server, achieved by using Session/RTP.

(2) Streaming Media: 384kbps one-way data flow that Stream Server send to UE, achieved by using CBR/UDPAgent.

(3) Interactive services: burst connection UE sends to HTTP Server. According to the Poisson Process of parameter 1, UE initiates request to the servers, achieved by using HTTP/Server/TcpAgent.

(4) Background services: file download that UE requests from the FTP Server, achieved by using FTP/TcpAgent.

4.2. Assessment

Shown here is a 30s simulation time. UE gradually increased from 10 to 100 is QoS changes of network traffic, and it compares the improved VQ-RED with HVQ performance proposed by Qiu.

The network throughput performance of the two schemes is shown in Figure3. Red line with “normal” marked is the original scheme, while green line with “Proposal scheme” marked is improved scheme. It can be seen from the picture that with the original scheme when UE is 80, network congestion occurs, while in improved scheme when UE is 90 the network throughput is still a small margin improved, and until the UE is 100 the throughput decreases significantly.

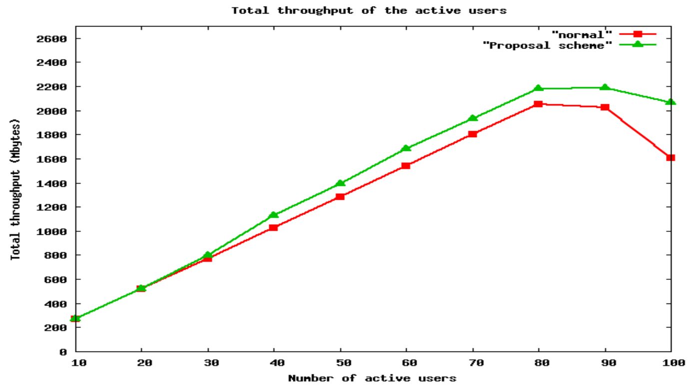

Fig.3: Total throughput

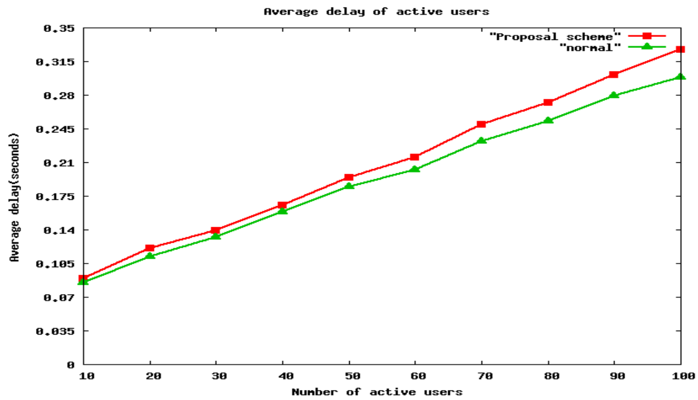

Fig.4: Average delay

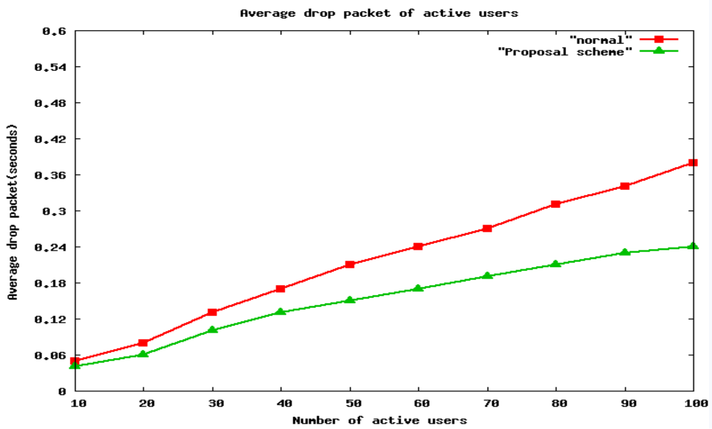

Fig.5: Packet Loss Rate

Average delay shown in Figure4, we can see improved scheme has increase the delay because it maintains a more stable virtual queue. Figure 5 shows the improvement program were selected because of packet loss, congestion control to avoid the effects of packet loss is not obvious, the packet loss rate has been significantly reduced, enhancing network reliability.

5. Conclusion

This paper proposed a kind of buffer management mechanism of LTE/SAE P-GW node in the application layer and introduces selection mechanism of packet loss on the base of VQ-RED-based congestion control. At the same time, the paper carried on verification by using LTE/SAE simulation platform under the NS2. The simulation result shows that the scheme improved throughput while reducing latency and packet loss rate. Later research work will focus on the time cost optimization scheme brought by carrying on TCP flow count and the update of the above 3 parameters in the case of PDP context increasing continually. At the same time, it will focus on providing a faster dropping packets option.

6. Acknowledgements

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