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Stability of Active Queue Management Schemes in Wireless Network: An Experimental Comparison

Atheer F. Hassan, Suhaidi Hassan and Suki Arif
InterNetworks Research Lab, School of Computing, Universiti Utara Malaysia (UUM), 06010 Sintok, Kedah, Malaysia

Abstract: Stable and predictable queue size is one of the main goals of the Active Queue Management (AQM) in Internet routers. Since, WLAN has a very transit with rapidly changed behavior due to its flexibility and mobility and varying capacity and delay due to the fading which considered the main reasons behind queue instability. Thus, this study is studying the stability performance of different AQM schemes in WLAN environment by developing an experimental simulation model that reflects the rapidly changing behavior of IEEE 802.11 based wireless networks. The result is showing that none of the tasted AQM schemes has achieved a stable queue and new algorithms that can stabilize the queue in WLAN environment are needed.

Key words: Packet queuing, routers, IEEE 802.11, experimental evaluation, performance, Malaysia

INTRODUCTION

The Active Queue Management (AQM) algorithms internet routers, for example (Floyd and Jacobson, 1993; Floyd *et al*., 2001; Feng *et al*., 2002; Athuraliya *et al*., 2001; Kunniyur and Srikant, 2004, 2003) are designed with several objectives in mind. However, the stability of the queue size (in terms of low queue size variance) plays a significant role in this list as it is strictly connected with other requirements. For instance, an AQM that can maintain a very low variance of the queue size guarantees also that the achieved throughput is close to maximal possible one. This is due to the fact that the empty queue probability is very low in a system with such AQM. Therefore, a stable queue size automatically provides a good throughput.

The other important objective of the active queue management is a low queue size. Obtaining a stable but long queue is not a very demanding task and even a simple drop-tail algorithm can do that to some extent. Therefore, these two requirements, stable and short queue size have to be always presented together.

There are many factors can affect queue instability. In particular (Ren *et al*., 2005), a large propagation delay was identified as the reason of instability of several popular AQM algorithms. Besides, there are two factors that have been investigated by Mrozowski and Chydzinsk (2009) which are low congestion level and low average queue size. Moreover, Adams (2013) demonstrates that the rapidly changed of number flows is one of the main factor that can cause queue size instability.

WLAN has grown dramatically in last couple decades and it is becoming a compulsory in all of the mobile devices and laptops due to its widely usage to access the internet anytime, anywhere. The main idea behind the wireless network is using the flexibility of radio waves based on IEEE 802.11 stander instead of wires to transfer the data from point to point that is giving WLAN the flexibility and mobility. Due to these characteristics, the wireless nods can connect, disconnect or even moving from one access point to another rapidly. This rapid changing will cause instability in the network which will cause the queue instability as well (Kunniyur and Srikant, 2004; Pletka *et al*., 2003).

This study is studying the stability performance of different AQM schemes in WLAN environment since most of them dealt with the case of wired networks. Unlike wired link which is assumed to have a fixed capacity and delay, a wireless link has varying capacity and delay due to the fading beside a rapidly changing environment due to the flexibility of radio waves which is considered the main factor that can affect queue stability (Tse and Viswanath, 2005). However, there are very limited studies that tackles AQM performance in WLAN environment and even fewer that tackles the queue stability. Therefore, this study tries to provide significant insight into AQM domain by studying the stability performance in such transient environment throw experimental analysis. Moreover, most of the literature have study the stability by using a mathematical method which is trying to find the stability region using both linear and nonlinear mathematical approaches. Thus, developing a simulation

Corresponding Author: Atheer F. Hassan, InterNetworks Research Lab, School of Computing, Universiti Utara Malaysia (UUM), 06010 Sintok, Kedah, Malaysia

model that can test the performance of stability is very challenging. As this study proposed an experimental model to tackle the stability in WLAN by following the suggestions and recommendations by Adams (2013).

Literature review: There are several studies have been published that focuses on studying the stability region on the AQM which have to be studied by complete model together with Transmission Protocol (TCP) such as the work that proposed by Misra *et al*. (2000). Flowing will briefly mention some study that have tackle the stability issue.

Hoillot and Chait (2001) has published in 2001, the authors have proposed the region attraction method by linearizing the non-linear fluid-flow model of TCP/AQM system. They address that proportional marking probability function has established some stability results.

Moreover, Wu *et al*. (2001) have been published as well in this study the sensitivity of RED algorithm under various network configurations. It proposed the study by modeling the closed-loop congestion control systems in a differential fluid flow model. It stated the limits of RED against deploying it in high speed network switches.

Bauso *et al*. (2004) have discussed the stability of AQM in multi bottlenecks models. They consider RED configurations for control theoretic techniques. It concluded that instability may rise in two links congestion scenario.

Also Tan *et al*. (2006) has conducted the TCP/RED system to study the stability of time-delay control theory on network stability. The results showed that stability can be achieved when RED parameters configured accordingly to the network condition.

At 2009, Mrozowski and Chydzinski (2009) have been published, it conducted several model to study the factors that effects stability in router buffers. They clearly found that networks with large delay, low congestion level and low queue size is the main factors that effects the stability and even the best known AQMs could not survive under these conditions.

AQM algorithms: There are many schemes and algorithms have been proposed to increase the buffer stability, some of these algorithms have its own novel mechanisms and some of them have just improvement from the previous algorithms each one has its own advantages and drawbacks. This study will survey some of significant impact algorithms in terms of stability such as Random Early Detection (RED), Random Early Marking (REM), Adaptive Virtual Queue (AVQ) and Controlled Delay (CoDel).

RED is the first formal AQM that have been proposed to be deployed instead of Droptail queue algorithm in TCP/IP networks (Floyd and Jacobson, 1993). RED is a queue-based AQM with no per-flow information that provide the network with a congestion avoidance mechanism. RED has been designed to minimize queueing delay by controlling the queue lengths in low values, preventing the interconnection between global synchronization and packet dropping, reduce the packet loss and achieve higher link utilization than Droptail (Ryu *et al*., 2004). If the average queue length is below the minimum threshold (minth) the RED will work normally without any changes but if it increased between minth and maximum threshold (maxth) the RED starts to drop incoming packets strained by proportional probability function to reduce average queue length. When the average queue length increase above the maxth RED will drop all incoming packets without any exception.

REM has been proposed by Athuraliay *et al*. (2001). REM is an AQM scheme that designed to attain high link utilization with negligible loss and delay in stable and simple manner. The main difference between REM and RED is the congestion measure and the probability function for dropping/marking. The key idea behind REM is achieving its targeted queue length for low delay and targeted rate for high utilization independently of network congestion by decupling the congestion measure from the performance measure and reaching the global optimal performance point (Kwon and Fahmy, 2002).

AVQ (Kunniyur and Srikant, 2004) is a rate-based AQM that maintains varrival rate at a targeted utilization. AVQ has been designed based on Kelly (2001) optimization approach by Kunniyur and Srikant (2004). The probability function of AVQ has derived from M/M/1/B loss probability (Kunniyur and Srikant, 2003).

CoDel is the latest AQM proposed by Nichols and Jacobson (2012). It has been built and designed to solve a full buffer problem “bufferbloat” in network by limiting the packet queue delay that happened in the network links (routers). CoDel tries to enhance overall performance of the network by reducing the delay and packet loss with high link utilization and throughput.

MATERIALS AND METHODS

Experimental model and simulation setup: According to Adams (2013), the performance of AQM scheme should not dramatically changed due to the sudden change in the network condition. It is important for AQM scheme to avoid oscillations between buffer underflows and overflows which surely leads to under link utilization and

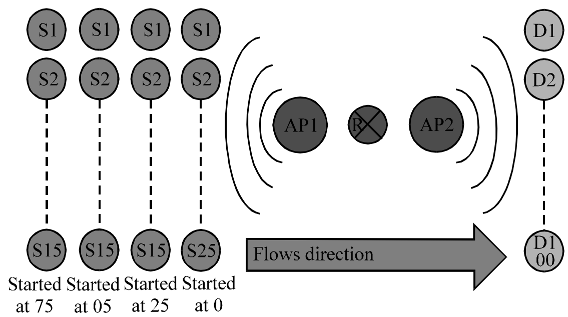

Fig. 1: Single link Bottleneck

Table 1: Simulation parameters

Parameters	Values
Simulation topology	Dumbbell
Flow type	Responsive (FTP over TCP-Reno) unresponsive (CBR rate 180 Kbps) short flows (FTP with high RTT)
Packet size	1000 bytes
MAC protocol	Ethernet 10 Mbps IEEE 802.11
Queue size	100 packets
RTT	60 msec responsive flows
Simulation time	100 sec
RED	
Maxth	80
Min.th	20
Maximum probability	0.1
w_q	0.002
AVQ	
y	0.98
α	0.8
REM	
γ	0.001
α	0.1
ϕ	1.001
CoDel	
Target	0.005
Interval	0.1

oscillation in queue delay. Moreover, the suggested stability taste is to measure the queue length when the number of connections flowing through the queue suddenly increases.

The experiment scenario will be executed on bottleneck topology (dumbbell) which had been studied and approved as suitable topology for testing and evaluating the performance of different types of AQM (Adams, 2013). The AQM schemes has been tested under a single wired link that contains one router nod in the middle of two Access Points (AP) which is connected wirelessly to 100 sources and 100 destinations in each side as shown in Fig. 1. Three different types of flows will be applied on the sources. First, 15 FTP flows transferred over TCP-Reno links with 1000 bytes packet size. Second, 5 UDP (transmission rate 180 Kbps) flows will be implemented on CBR packets. Third, 25 short flows represented by sources that used TCP with fixed number of packets. This scenario has run for 100 sec time long; the rest of parameters can be found in Table 1. The simulation started with 25 responsive sources and the rest is divided to three groups. Each group consisted of 5 sources from each type (responsive, nonresponsive and short flows). These 3 groups started sending the data at second 25th, 50th and 75th, respectively as shown in the Fig. 1.

RESULTS AND DISCUSSION

Simulation results: Monitoring the queue length is very important to analyze the behavior of AQM schemes in terms of stability. However, queue length is not enough to evaluate the AQM schemes stability performance. Thus, the result has conducted by comparing the queue length with the queue lost to get a better picture on AQM behavior in terms of stability.

Firstly, RED started with average queue length and low queue lost and the lowest value is when the simulation reaches 25 sec. But, after the 25 sec the first group start send their data and the queue length takes the first jump from 13-25 packets and start increasing after then.

When the simulation reaches 50 sec queue length took the second jump from 38-71 packets with the dramatic increasing in the queue drop. Furthermore, when the last group start send their data the queue length took the last jump from 50-80 packets with the jumping in the queue drops as shown in Fig. 2.

REM has unstable behavior as well. It started with low queue length and queue drop but it kept jumping from 30-50 packets from 70-80 packets and from 74-98 packets at 25, 50 and 75 sec, respectively alongside with increasing in the queue lost as shown in Fig. 3.

On the other hands, AVQ has unstable behavior when the network condition changed as shown in Fig. 4. It is easy to find the point that queue length is changing together with the increasing of the queue lost. So, when the number of sources increase the queue length increases as well as queue lost.

CoDel has unexpectedly low queue length. It ranges between 0-9 packets but this low queue length comes with price of trading a very high queue lost which increases dramatically as shown in Fig. 4 and 5.

From all above, it becomes obvious that none of the AQM schemes were able to keep a stable queue size during the experiment. However, CoDel has achieved the lost queue size comparing with the rest due to its ability to penalize all flows based on the time the its packets took

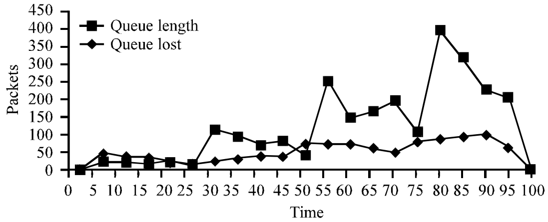

Fig. 2: Queue length vs. queue loss for RED

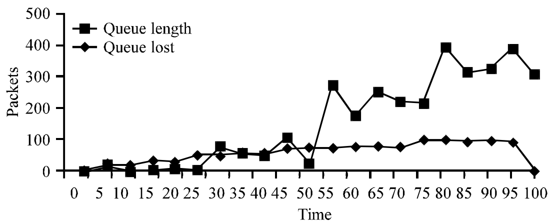

Fig. 3: Queue length vs. queue loss for REM

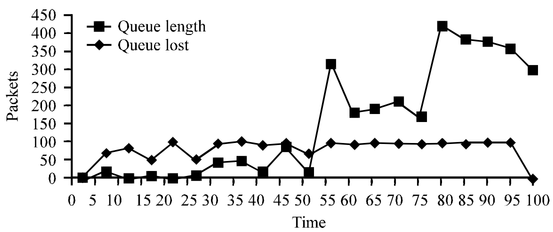

Fig. 4: Queue length vs. queue loss for AVQ

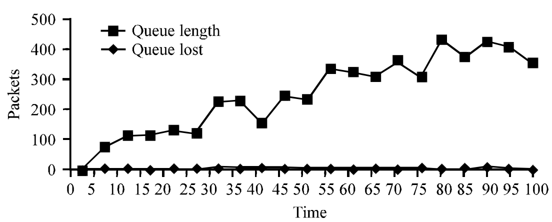

Fig. 5: Queue length vs. queue loss for CoDel

in the buffer strained by the time interval to drop the packets which is the main reason behind CoDel queue lost is very high. On other hand, REM and AVQ managed to have higher queue length where REM has gradually increasing size, better than AVQ that have the highest queue size among the rest. However, RED has the most instable behavior among the rest, the queue size is keep jumping every time that number of flows increase.

CONCLUSION

This study has studied the performance of AQM schemes in IEEE 802.11 based wireless network environment in terms of queue stability by developing an experimental simulation model. The results demonstrated that none of the tasted AQM schemes has achieved a stable queue. However, CoDel (newest AQM) has managed to keep the queue size very low but this comes with the price of high queue lost. Whereas, REM and AVQ has a higher queue length comparing with the rest. Moreover, RED has the worst performance in terms of stability. Therefore, new algorithms that can stabilize the queue in WLAN environment are needed.

REFERENCES

Adams, R., 2013. Active queue management: A survey. IEEE. Commun. Surv. Tutorials, 15: 1425-1476.

Athuraliya, S.A., S.H. Low, V.H. Li and Q.H. Yin, 2001. REM: Active queue management. IEEE Network, 15: 48-53.

Bauso, D., L. Giarre and G. Neglia, 2004. About the stability of active queue management mechanisms. Proceedings of the Conference on American Control Vol. 4, June 30- July 2, 2004, IEEE, Boston, Massachusetts, ISBN:0-7803-8335-4, pp: 2954-2959.

Feng, W.C., K.G. Shin, D.D. Kandlur and D. Saha, 2002. The BLUE active queue management algorithms. IEEE/ACM Trans. Networking, 10: 513-528.

Floyd, S. and V. Jacobson, 1993. Random early detection gateways for congestion avoidance. IEEE/ACM Transa. Networking, 1: 397-413.

Floyd, S., R. Gummadi and S. Shenker, 2001. Adaptive RED: An algorithm for increasing the robustness of RED's active queue management. IOSR. J. Comput. Eng., 2: 20-24.

Hollot, C.V. and Y. Chait, 2001. Nonlinear stability analysis for a class of TCP/AQM networks. Proceedings of the 40th IEEE Conference on Decision and Control Vol. 3, December 4-7, 2001, IEEE, Orlando, Florida, ISBN:0-7803-7061-9, pp: 2309-2314.

Kelly, F., 2001. Mathematical Modelling of the Internet. In: Mathematics Unlimited-2001 and Beyond, Engquist, B., W.S.B. Engquist and S. Wilfried (Eds.). Springer, Berlin, Germany, ISBN:978-3-642-63114-6, pp: 685-702.

Kunniyur, S. and R. Srikant, 2003. End-to-end congestion control schemes: Utility functions, Random losses and ECN marks. IEEE/ACM Trans. Network., 11: 689-702.

Kunniyur, S.S. and R. Srikant, 2004. An Adaptive Virtual Queue (AVQ) algorithm for active queue management. IEEE. ACM. Trans. Netw., 12: 286-299.

Kwon, M. and S. Fahmy, 2002. A comparison of load-based and queue-based active queue management algorithms. Proceedings of Conference on SPIE ITCom: The Convergence of Information Technologies and Communications, July 29, 2002, Rochester Institute of Technology, Boston, Massachusetts, pp: 1-13.

Misra, V., W.B. Gong and D. Towsley, 2000. Fluid-based analysis of a network of AQM routers supporting TCP flows with an application to RED. ACM SIGCOMM Comput. Commun. Rev., 30: 151-160.

Mrozowski, P. and A. Chydzinski, 2009. On the stability of AQM algorithms. Intl. J. Appl. Math. Inf., 3: 276-281.

Nichols, K. and V. Jacobson, 2012. Controlling queue delay. Commun. ACM., 55: 42-50.

Pletka, R., M. Waldvogel and S. Mannal, 2003. PURPLE: Predictive active queue management utilizing congestion information. Proceedings of the 28th Annual IEEE International Conference on Local Computer Networks, Oct. 20-24, IEEE Computer Society, Washington DC., pp: 21-30.

Ren, F., C. Lin and B. Wei, 2005. A robust active queue management algorithm in large delay networks. Comput. Commun., 28: 485-493.

Ryu, S., C. Rump and C. Qiao, 2004. Advances in Active Queue Management (AQM) based TCP congestion control. Telecommun. Syst., 25: 317-351.

Tan, L., W. Zhang, G. Peng and G. Chen, 2006. Stability of TCP-RED systems in AQM routers. IEEE. Trans. Autom. Control, 51: 1393-1398.

Tse, D. and P. Viswanath, 2005. Fundamentals of Wireless Communication. 1st Edn., Cambridge University Press, Cambridge, UK., ISBN-13: 9780521845274.

Wu, W., Y. Ren and X. Shan, 2001. Stability analysis on active queue management algorithms in routers. Proceedings of the 9th International Symposium on Modeling, Analysis and Simulation of Computer and Telecommunication Systems, August 15-18, 2001, IEEE, Cincinnati, Ohio, ISBN:0-7695-1315-8, pp: 125-132.