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Predictive Model for Congestion Control in QUIC Protocol Based Network

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Abstract:The handshaking mechanism of transmission control protocol (TCP) plays important role for congestion avoidance in most of the networks. The streaming based services require more data speed with best effort delivery mechanism. The requirement is satisfied in most of the networks with the use of user datagram protocol (UDP). With more losses accommodation mechanism UDP is acceptable up to the limit of congestion due to multiple streaming pressures on the network. The window management mechanism of TCP is good but hampers the speed which shows its incapability of streaming services applications. The combination of TCP and UDP is considered during development of QUIC protocol. The streaming protocol released by google for useful in chrome is considered as base protocol and further predictive model is developed for window management mechanism which then improves the performance of the network with the control of congestion events. The recurrent neural network (RNN) based model is developed which uses long short term memory (LSTM) and gated recurrent unit (GRU). The model shows improved capacity to identify the congestion event and avoids the congestion with forecasting based on historical records.

Keywords: LSTM, RNN, Neural network, Congestion, QUIC, prediction

I. Introduction:

The bandwidth utilization and streaming service requirement is growing day by day due to vast internet users. The streaming service requirements and its respective impacts on data losses due congestion events is serious consideration which shows scope for the researchers to develop more modest methods. The congestion event is possible to detect after its occurrence and is managed with adaptive window management mechanism with control of data speeds. The time lapse during the detection of event and then management of window seriously affects the latency of the network. This problem is addressed in this paper with neural network based forecasting approach.

The QUIC protocol is developed by google which is mainly used in chrome browser with respect to user recommended settings. The streaming of data is done seamlessly when use of QUIC is enabled. The network configuration can be considered when all the nodes within the network are using QUIC protocol and demanding the streaming service.

As compared to transmission control protocol (TCP), the similar acknowledgement mechanism is used in QUIC protocol which plays important role of window management mechanism. The number of acknowledgements in QUIC are reduced in number compared to TCP, which improves the data speed and reduces the control packet overhead. The user datagram protocol (UDP) has no acknowledgement mechanism and hence it is prone to more losses during the congestion events and also remains uncontrollable during the event. The combinational mechanism of QUIC protocol shows more scope for improvement to avoid occurrence of congestion events as far as flow based network is considered.

In this paper a network with software defined network (SDN) controller is considered in which flow based data delivery is configured and congestion events avoided with the model proposed. The novel proposed model is detailed in section III and results of which are evaluated in section IV which shows satisfactory performance.

II. Related work:

The paper [1] dismembers the explanations behind this condition, and a short time later discussions about the upsides of Google's preliminary QUIC show in far off transmission and finds that QUIC is definitely not hard to extend and pass on, giving a good structure to redid smoothing out. This applies the QUIC framework and presents a QUIC headway estimation for the VPN or LAN circumstances, which essentially improves the blockage figuring dependent on QUIC. Through diversion tests, it is found in the distant condition with high lethargy and high package adversity rate, the QUICMING-based HTTP applications perform inside and out superior to those subject to TCP, SPDY and default QUIC.

In paper [3] changed PUMA guiding show improves the framework execution to the extent imperativeness use and transmission frustrations. It diminishes the pile on far off center points by picking the course with least essentialness with most noteworthy bounce count. Also, besides SMAC is used to save the essentialness assessments of far off center points. In multicast condition, by brushing both of these techniques to fabricate the framework execution to the extent imperativeness use, transmission dissatisfactions, pack dropping and from beginning to end delay.

The paper [4] presents an administrator based stop up control strategy for flexible masters (MA). An adaptable administrator based stop up control AODV guiding show is proposed to avoid blockage in exceptionally designated framework. Some flexible administrators are accumulated in extraordinarily designated framework, which pass on guiding information and center point's blockage status. Right when versatile pro improvements through the framework, it can pick a less-stacked neighbor center as its next bounce and update the coordinating table according to the centers obstruct status. With the assistance of convenient administrators, the centers can get the dynamic framework topography in time. By reenactment results, we have shown that our proposed

technique achieves high movement extent and throughput with decreased delay when differentiated and the particular existing methodology.

The paper [5] proposes a cutoff time careful stop up control instrument, taking into account a meaning of the traditional TCP New Reno blockage control framework. By considering the open cutoff time information, the change of the blockage window is capably acclimated to control the forcefulness of an idea about stream. The procedure has been through and through evaluated in both a video-on-demand (VoD)- just circumstance and a circumstance where VoD streams harmonize with live streaming gatherings and non-cutoff time careful traffic. It was shown that in a video moving circumstance the irrelevant bottleneck information transmission can be lessened by 16% on typical while using cutoff time careful obstruct control. In simultaneousness with other TCP traffic, a bottleneck decline of 11% could be cultivated.

The paper [6] investigates the characteristics of TCP based RENO, new RENO, Vegas and SACK shows. Generation was performed to consider the introduction of the shows similar to Bandwidth, diversion time and number of traffic sources. The outcomes of the reenactment demonstrated that Reno is adequate when package incidents are pretty much nothing. New Reno is viewed as important when there are more adversities of data. Sack is viewed as enthusiastic when various incidents occur in one obstruct window Vegas is the best while contrasting information transmission inferable from the usage of time based exchange speed assessment intends to control its blockage.

The paper [6] proposes the Multi-TCP system, an authority driven, TCP-based structure for sight and sound moving over the Internet. The proposed count targets invigorating against SHORT TERM lacking information move limit by using MULTIPLE TCP relationship for a comparative application. Plus, our proposed system engages the application to achieve and control the ideal sending rate during stopped up periods, which can't be cultivated using regular TCP.

The paper [7] addresses the stop up control plot in TCP based multi jump distant frameworks. Unequivocal distant blockage control show (EWCCP) is introduced. By mishandling express coordination and multi bit unequivocal contribution from switches, EWCCP builds fine grain control, which adjust smaller yet ideal sending window size appeared differently in relation to TCP. The show introduced allots resources sensibly among center points which look for the regular channel. Connection with TCP shows pleasant results for tolerability and blockage control. The data rate improvement approach isn't considered in the paper.

III. Proposed work:

The proposed work consists of congestion detection using RNN based neural networks with prediction mechanism. Following set of assumptions are considered while proposing the work.

1. The network should be consist of flow based mechanism
2. The network should be operated using QUIC protocol as transport layer for streaming applications.
3. Maximum demand from multiple clients should be considered as congestion event with respect to predefined threshold level.

By considering assumptions network configuration using open flow simulator, Mininet is used to configure the network. The network configuration is made with hierarchical structure using multiple switches in the network and with SDN controller.

The bottleneck effect is generated using hierarchical structure and by setting up bandwidth limit at the switch with respect to data generation speed from the server. Server is set to handle the bandwidth 10 times than the demand and bandwidth at the switch is set to exactly equal to the demand from associated nodes. Figure 1 shows the network configuration used in the experimentation.

The congestion event is recorded with respect to time delays in the ACK packets reception. Firstly normal delays of ACK packets are measured by counting time from sent packets time instant. The congestion packet delay is also counted based on which congestion events can be recognized.

This can be given as,

Change in delay due to congestion= Delay due to congestion-delay in normal condition … (1)

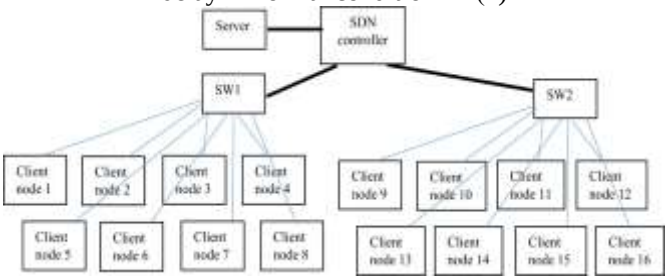

Figure 1: Experimental Netowrk configuration

In equation (1), the delay due to congestion varies abnormally with respect to bandwidth and other un recognizable network causes. Hence perfect congestion event prediction using ACK delay analysis can not provide optimal solution. Hence, along with ACK delays other network characteristics are also considered based on which numeric values are obtained which contains,

1. Total number of flows that demand streaming service
2. Total number of packets sent already before arrival ACK
3. Bandwidth utilization
4. Actual window size used to deliver data for all the flows linked currently
5. Number of window decrement events required by considering ACK delays
6. Maximum time passed by association node for the demand of the video streaming

By considering the numeric values enlisted, the feature vector is formed by considering switch1 and switch2 at a time and also considering both simultaneously in congestion state. All the data is recorded for common video demand. The congestion event is also verified before labelling as congestion by using packet delivery ratio, throughput and average end to end delay.

With verified labelled dataset, neural network based congestion event prediction model is proposed. The proposed congestion detection model is shown in figure in which multiple neural network models are compared based on performance of predicting the congestion event. Figure 2 shows the congestion detection work proposed in this paper.

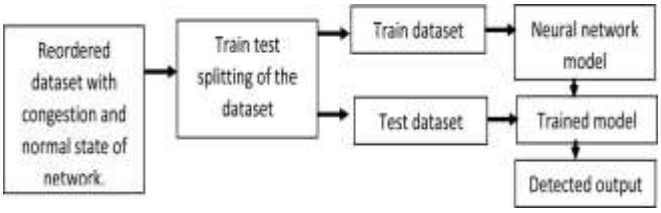

Figure 2: Proposed neural network work flow

The neural network models used for the experimentation are, recurrent neural network models developed with the use of LSTM and GRU based model is configured as shown in table 1.

Table I: Proposed Neural Network Layer Model configuration

Layer	Output Shape	Parameters
gru (LSTM)	(None,1,7)	70656
Dropout	(None,1,128)	0
lstm_1(LSTM)	(None,64)	8256
Dropout_1	(None,64)	0
Dense_1	(None,2)	130
Total Parameters:	8256	
Trainable Parameters	210,626	
Non-trainable Parameters	0	

Based on true or false event prediction the congestion state is detected. Also, adaptive window management mechanism is used to avoid the congestion state. For every packet sent and received, congestion state is predicted which does not involve the network communication of control packets but on the other hand network congestion state is predicted to decide the window size. Initially, window size is set maximum and then it is reduced if congestion state is predicted by the model otherwise no change is made in the size. The congestion state based window reduction events and respective congestion occurrence events is the main measure of the performance evaluation strategy.

The dense layer at the output provides class label of the congestion event.

IV. Results and analysis:

The performance of the deep learning model depends on the actual state of the network and predicted state of the network. The performance based on true positive, false negative, true negative and false positive parameters are observed. The formulae for estimation accuracy, sensitivity and specificity are shown in table II.

Table II: Parameters formulae

Parameter	Formula
Sensitivity	TP/(TP+FN)
Specificity	TN/(TN+FP)
Accuracy	TP+FN/(TP+TN+FP+FN)

Performance evaluation:

Performance valuation is shown in table III for the prediction of congestion events with respect to change in number of flows in the network. The RNN based deep network shows better performance compared to all other classical classifiers.

Table III: Performance of Congestion event forecasting accuracy of proposed model with respect to number of flows.

Number of flows	Accuracy	Sensitivity	Specificity
20	0.98	0.91	0.89
40	0.963	0.90	0.875
60	0.958	0.89	0.86
80	0.928	0.88	0.84
100	0.918	0.88	0.84

Along with performance of congestion detection, the performance in terms of throughput is observed and compared with TCP, QUIC protocols as shown in table IV to VI and figure 3 to 5 for data rates 800kbps to 2400kbps and different number of flows.

Table IV: Throughput analysis for different number of flows for data rate 800 kbps

Index	Number of flows	TCP	UDP	QUIC	Modified QUIC
1	20	356.12	468.63	526.44	562.90
2	60	386.00	520.90	610.40	690.40
3	100	451.60	593.60	630.80	710.20

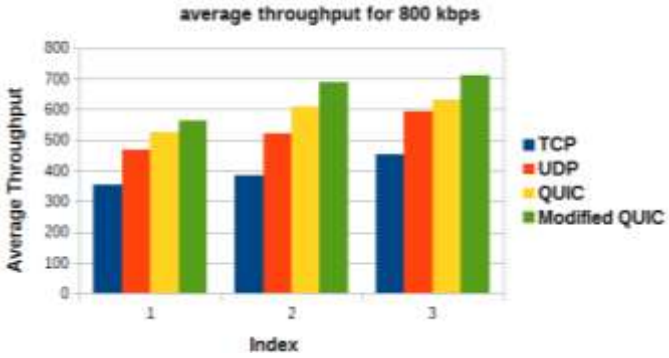

Figure 3: Average Throughput Analysis for data rate 800kbps

Table V: Throughput analysis for different number of flows for data rate 800 kbps

Index	Number of flows	TCP	UDP	QUIC	Modified QUIC
1	20	405.98	534.24	600.14	641.71
2	60	440.04	593.83	695.86	787.06
3	100	514.82	676.70	719.11	809.63

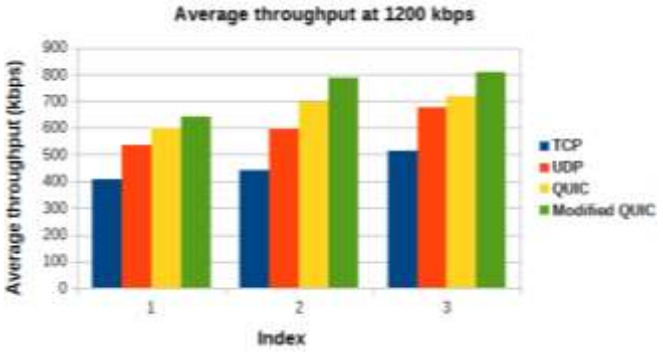

Figure 4: Average Throughput Analysis for data rate 1200kbps

Table VI: Throughput analysis for different number of flows for data rate 2400 kbps

Index	Number of flows	TCP	UDP	QUIC	Modified QUIC
1	20	423.43	557.21	625.95	669.30
2	60	458.96	619.36	725.78	820.90
3	100	536.96	705.80	750.03	844.44

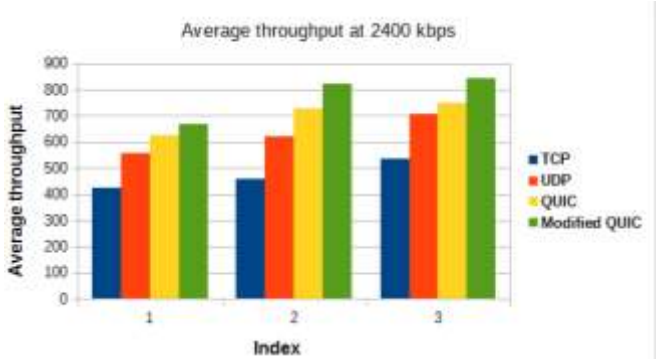

Figure 5: Average Throughput Analysis for data rate 2400kbps

The average throughput at different datarates of the nodes for streaming of data and with different number of nodes or flows in the network shows significant changes. The overall analysis shows that modified QUIC protocol outperforms over TCP, UDP and QUIC protocols due to congestion forecasting mechanism.

V. Conclusion

The congestion forecasting helps to take early decision for congestion avoidance and along with this reduction additional control packets overheads for the mechanism compared to other protocols which use control packets to detect the congestion. Also, dynamic window management mechanism due to congestion forecasting and avoidance mechanism improves the overall successful data delivery at the destination. The simulator based experimentation shows that modified QUIC protocol with neural network model for congestion forecasting and avoidance with dynamic window management improves the throughput of the entire network.

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