# IMPLEMENTATION OF NEW TCP CONGESTION CONTROL MECHANISM OVER LONG TERM EVOLUTION ADVANCED NETWORKS

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ABSTRACT

Long Term Evolution-Advanced (LTE-Advanced) should be real broadband wireless network that provides peak data rates equal to or greater than those for wired networks. The major high-level requirements of LTE-Advanced are reduced network cost (cost per bit), better service provisioning and compatibility with 3GPP systems. This paper presents a new mechanism to improve the performance of Congestion Window (*cwnd*) by using a new mechanism that supports bandwidth estimation to detect the capacity of network path. That will enhance the TCP ability to send a large possible amount of packets from source to destination through LTE-Advanced model by using Network Simulator NS-2. The new algorithm through simulation and modeling experiments and from the obtained results achieves the required congestion window with high efficiency.

*Keywords:* TCP, congestion control, LTE, LTE-Advanced.

## INTRODUCTION

As the development of LTE, LTE-Advanced must be compatible backwards in the sense that it should be possible to deploy LTE-Advanced spectrum already occupied LTE with no effect on existing plants LTE, to include the possibility for data rates of up peak to 1 Gigabit per second in the downlink and 500 Mbps in uplink (Parkvall *et al.,* 2008). However, more important than the peak data rates is the possibility of providing high data rates over the greater part of the cell. While LTE Rel.8 supports peak data rates exceeding 300 Mbps in the downlink (DL) and 75Mbps in the uplink (UL), LTE is expected to provide advanced Rel.10 up to 1Gbps in megabits per second and DL 500 UL in environments in the navigation low (Bou Saleh *et al.*, 2010). When using TCP over the cellular infrastructure, and the result is that both times the end-to-end production and use of radio link is very weak. This is because the dynamic characteristics of TCP and wireless connections do not fit well together (Möller *et al.,* 2005). TCP limits its sending rate by controlling the congestion window (*cwnd*) size, which is the number of packets that may be transmitted in a flow. The time between delivering a packet and receiving its ACK is a round-trip time (RTT). A TCP sender can send up to the *cwnd* size of packets during one RTT. Therefore, the average rate of a TCP over one RTT is roughly the window size divided by the RTT (Choi *et al.,* 2006).

## LTE-ADVANCED SYSTEM ARCHITECTURE

LTE is the leading Orthogonal Frequency-Division Multiple Access (OFDMA) wireless mobile broadband technology. LTE offers high spectral efficiency, low latency and high peak data rates. LTE/LTE-Advanced leverages the economies of scale of 3G, as well as the ecosystem of infrastructure and devices vendors to provide the highest performance in a cost effective manner (Khandekar *et al.,* 2010). The notion of LTE technology depends on the understood that it improves system performance in terms of data rate, throughput, latency, coverage and cost. LTE offers a pure packets assigned architecture, with viability of the movement management. The latest step being studied and developed in 3GPP is an evolution of 3G into an evolved radio access referred to as the LTE and an evolved packet access core network in the System Architecture Evolution (SAE) (Parkvall *et al.,* 2008).

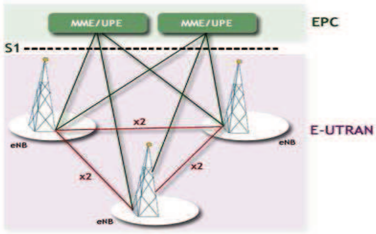


FIGURE 1 LTE-Advanced E-UTRAN and EPC architecture

The architecture which is considered for 3GPP is shown in Figure 1. E-UTRAN architecture based on, eNodeB which acts as a base station, and called E-UTRAN Node B. MME represents the Mobility Management Entity. S-GW is a serving gateway, and last, P-GW is a PDN (Packet Data Network) Gateway. Each eNodeB are connected to the MME/SAE Gateway by the S1 interface where as X2 interface is interconnecting the eNodeBs (or eNBs). The X2 interface is used also on U-plane for temporary user downlink data. The main task of MME/SAE Gateway is to distribute the migration of messages to eNBs; security control; encryption of user data, switching of U-plane to support of UE mobility; idle mode mobility handling (Bajzik *et al.,* 2007).

## CONCEPTS OF NEW CONGESTION CONTROL MECHANISM

Primary role, to control congestion, is adjust the window of data transmission at sender side in such a way that is preventing buffer overflow in the recipient, but also in the intermediate routers. To achieve this, TCP used another variable to control congestion window called a (*cwnd*). The congestion control represents a number of segments of appreciation that can be injected in the network without causing congestion. The challenge is to take advantage of the available space in the store network routers. Routers do not participate in the TCP layer and the chip cannot be used to adjust the TCP ACK frame. To resolve this problem, TCP assumes network congestion as the retransmission timer expires, and that it interacts with the network congestion by adjusting the congestion window using two algorithms, a slow start and congestion avoidance, as shown in the Figure 2.

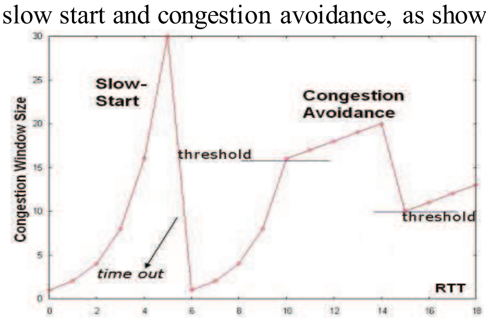


FIGURE 2 TCP Slow-Start and Congestion Avoidance phase

In proposed mechanism, we used classic exponential increment in Slow-Start phase. When congestion window less than Slow-Start threshold (*ssthresh*), the window size increases by one, as explained in equation (1):

$$\text{if (cwnd} < \text{ssthresh) then cwnd} = \text{cwnd} + 1; \tag{1}$$

The sender TCP updates its congestion window size in the congestion avoidance phase according to the following equation when it receives an ACK packet from receiver TCP as shown in equation (2):

$$\text{cwnd} = \text{cwnd} + (\text{f} / \text{cwnd}) \tag{2}$$

In proposed mechanism, we need to update *f* for equation (2) every time that TCP sender receives a new ACK packet. The proposed mechanism can accommodate the fluctuation of RTTs of the network path. In fact we depend on four main parameters to updates f values every RTT. These parameters illustrated below:

- *ssthresh*: slow-start threshold of network path.
- *cwnd*: the last value of *cwnd*.
- *wnd_const*: packets per RTT.
- *k_parameter*: *k* parameter in binomial controls.

One of big challenges to implementing the proposed mechanism is huge increment in *f* value. This state happened when the throughput of the network link is far less the next or expected throughput. This problem can cause lost in packets and flit in performance because of the extra periods in retransmission. When the proposed formula in equation (3) has obtained a high throughput, we need to minimize the value of *f* to avoiding packets losses. The control of this problem by divide the last value of *f* by the previous *cwnd* value multiplied by the exponent *cwnd* to the *k* parameter in binominal control as shown below:

$$\text{f} = \text{f} / (\text{cwnd} * \text{pow (cwnd, k\_parameter)}) \tag{3}$$

Finally, when TCP sender confirmed by new ACK, the new mechanism can updating the value of *f* according to the algorithm shown below:

```
/* Slow-Start Phase (Exponential Increment) */
    if (cwnd_ < ssthresh_)
        cwnd_ = cwnd_ +1;
/* Congestion Avoidance Phase */
else { f = wnd_const_ * ssthresh_ / cwnd_ * pow(cwnd_, k_parameter_);
            cwmd_ = cwnd_ + ( f / cwnd_);  }
```

## LTE-ADVANCED MODELING AND SIMULATION

LTE-Advanced modeling is generally more complex in nature than the traffic model used for a GSM or 3G system. In an LTE-Advanced system, the mobility management entity (MME) and the system architecture evolution (SAE) gateway communicate with the eNB by way of an S1 interface. For traffic transport, the S1 interface employs the hub-and-spoke model, which is similar to the traffic model of Iub interface in a 3G system. An X2 interface is used between eNBs in the LTE-Advanced system to ease the SAE gateway traffic load caused by frequent handover. However, using this type of interface greatly increases the complexity of the traffic model for backhaul networks, as shown in Figure 1. Theoretically, each eNB must have a direct physical or logical link with its neighboring eNBs in order to support X2 interfaces. The router aGW, connected to the server with duplex link (two ways) and Drop Tail, with bandwidth of 1Gbps, and propagation delay of 5 msec. The main job of aGW router is to control the flow rate of the streaming data from server to eNB-1, and eNB-2, so these two nodes, responsible for buffering the data packets for User Equipments UEs. Each eNB, connected to the corresponding aGW through wired simplex link (one way) of 10 Mbps bandwidth and 5 msec delay (Qui *et al.,* 2009).

The other main parameters of proposed LTE-Advanced topology used for all links one propagation delay of 5 msec, and the maximum packet size of TCP was set to 1500 Byte, with minimum window size of 48 Kbytes. Figure 3 represents the real topology animator created by NS-2 network simulator. The wireless nodes (UEs) linked to the corresponding eNB, through wireless link as mobile nodes, where the nodes 4 and connected to eNB-1 and eNB-2 respectively. Really, the UE nodes not have full mobility features, because they not move yet, and if we support the movement of these nodes we must add a Handover scenario to the topology, and this is not our goal in this research. The evaluation of new congestion control mechanism, already added to a new TCP. This new TCP have the same parameters and specification of other TCP source variants; only the congestion control algorithm changed. In first time, when this new TCP developed, and before supported by new congestion control mechanism, it was tested with constant function of congestion window; *cwnd* = h ; where h a constant value such as 40 (packets).

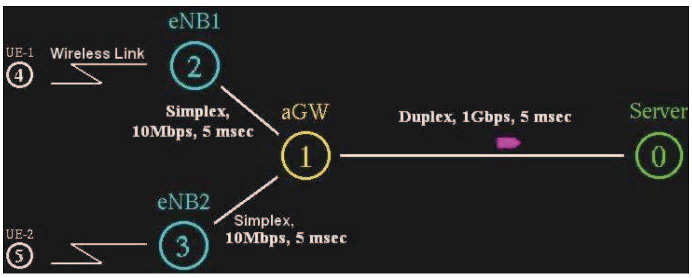


FIGURE 3 NS-2 Network Animator of Proposed Model

## RESULTS AND PERFORMANCE ANALYSIS

The measurement results of *cwnd* during the experiment explains that congestion window of new TCP performed well comparing with Reno congestion window, so the clocking of new TCP is also better than Reno clocking; in addition we have a smooth slow-start phase like Reno. Figure 4 shows the *cwnd* behavior in which the proposed mechanism can obtained and shows that the original TCP Reno have about of a half *cwnd* compared with *cwnd* obtained from new mechanism, where the new gave about 125packets as a maximum congestion point, but Reno kept the same previous value of 65 packets.

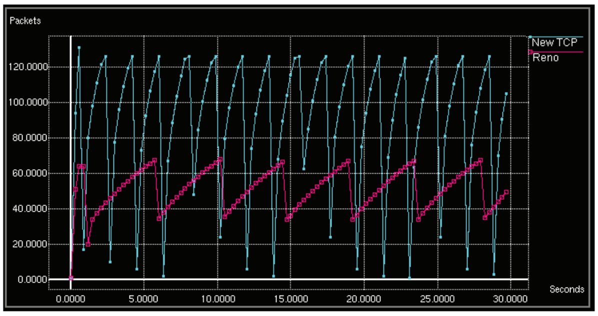


FIGURE 4 *cwnd* behaviors of new mechanism and Reno over 1Gbps bandwidth

On the other hand, the new TCP gave a performance speed more than twice that obtained from Reno, where every one complete cycle clock of *cwnd* in Reno we obtained more than two cycles in new TCP. That means we will send a more than double amount of packets in new mechanism. Finally, and for more accuracy, we performed more experiment with other five TCP variants, Newreno, Tahoe, Sack, Fack, and Vegas to achieving the full requirement to depend the new TCP as a new mechanism that support data transfer in LTE-Advanced systems with high performance and with more efficiency and reliability form other classic TCP variants, as shown in Figure 5. The new TCP will detect the current information on the available bandwidth and the physical capacity of the network path.

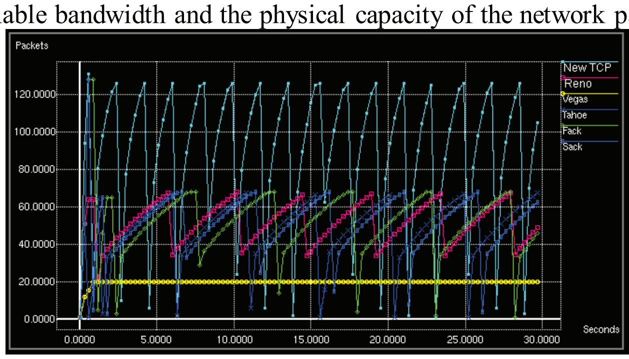


FIGURE 5 *cwnd* behaviors of new mechanism and six TCP variants over 1Gbps bandwidth

## CONCLUSION

This article focused on developing a new TCP with new congestion control with new methodology to work over LTE-Advanced systems. The mechanism proposed in this article improved the increment in congestion window size phase in congestion avoidance according to the parameters introduced by network and depending in other factors to determine the available bandwidth capacity before injecting packet to network pipeline. In our simulation experiments, the demonstration of the new TCP presented over traffic model of LTE-Advanced system and from results obtained that new mechanism achieved the required *cwnd* and produced a new congestion window with a clear difference if compared with classic source variants.

## ACKNOWLEDGEMENT

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