5G-TCP: Enhanced Transport Protocol for Future Mobile Networks

Ivan Petrov[1(✉)] and Toni Janevski[2]

[1] Sales Excellence Unit, Makedonski Telekom AD Skopje, Skopje, Macedonia
ivan.petrov@telekom.mk

[2] Faculty of Electrical Engineering and Information Technologies, Saints Cyril and Methodius University, Skopje, Macedonia
tonij@feit.ukim.edu.mk

Abstract. Next generation of mobile networks are expected to assure super fast data transfer with very low delay. The initial 5G standardization is expected to be finalized around 2020. Enhanced mobile broadband with its corresponding demand of higher capacity and end user data rates represents the key driver of 5G network development. The transport protocols are directly correlated with the traffic rate, so they must be kept in the focus and should be properly designed. In this paper we present 5G-TCP as new applicable solution that improves the protocol performances over super fast mobile networks.

Keywords: 5G · Congestion control · Mobile networks · TCP
Transport protocol

1 Introduction

The next generation networks will have to assure radically lower cost and energy consumption per delivered bit. The network must offer higher data transfer rates in static and mobile mode of operation mainly because the conventional mobile broadband applications will demand higher capacity and higher end user data rates [1–4]. Next Generation (NGN) and Future Networks are all-IP networks, meaning that all data, control and signaling will be carried through IP communication, based on the Internet technologies from network protocol layer up to the application layer, with different heterogeneous access technologies on the lower two layers of the protocol stack [5]. In that manner 5G networks are expected to be all-IP with higher bit rates in the access and core parts, and delays less than 1 ms in the mobile terrestrial access part, that requires continuing work on the Internet protocol stack, which is consisted of IP (Internet Protocol) on the network layer and TCP (Transmission Control Protocol) and UDP (User Datagram Protocol) on the transport protocol layer. Our objective is to find generally applicable solutions that improve the protocol performance over high speed wireless and mobile access networks, while maintaining the performance over wired links in the mobile (NGN-based) core network. TCP is common denominator for many services, therefore by modifying TCP [7–14] the need for applying solutions locally can be reduced. We have designed and evaluated version of high speed TCP named as 5G-TCP, protocol that could be implemented in the future super fast networks.

N. Oliver et al. (Eds.): MindCare 2016/Fabulous 2016/IIoT 2015, LNICST 207, pp. 119–125, 2018.
https://doi.org/10.1007/978-3-319-74935-8_17

The paper is organized as follows: Sect. 2 describes the basics of 5G-TCP, the simulation scenario and results are discussed in Sect. 3. Section 4 concludes the paper.

2 Description of 5G-TCP

It is interesting to notice that the function of parabola is generalized by rational normal curves which have coordinates ($x, x^2, x^3, \ldots x^n$), standard parabola is obtained when $n = 2$ and the case when $n = 3$ is known as twisted cubic which is used as response function by TCP Cubic protocol [11]. In the theory of quadratic forms the parabola function represents the graph of the quadratic form x^2. The curves $y = x^p$ for other values of p are referred as higher parabolas and are treated implicitly in the form $x^p = ky^q$. In accordance with this analysis we can find analogy with the standard TCP response function in time domain presented in the form as $2^{t/RTT}$, where RTT presents packet round trip time and t is the current time or with the cubic function written as x^3 with the form $y = x^p$. It is native to conclude that several TCP protocols use parabola or higher parabola as common protocol response function. We have decided to use parabola function instead linear interpolation [8] at log log scale in order to define $w(p)$. If we put series of circles in the same plane as the curve, by keeping one of the segments constant we can construct parabola. At Fig. 1 is presented construction of parabola with help of series of tangent circles passing through the point S. The segment SA is kept constant during the construction. The fixed horizontal line at A constructs geometric means between SA (constant) and the series of segments AT, AU, AV. These segments are plotted against the series of geometric means AX, AY, AZ to give the points A, B, C, D all of which lie along the parabola. The vertical distances of the points (B, C and D) form A are proportional to the square on their horizontal distances.

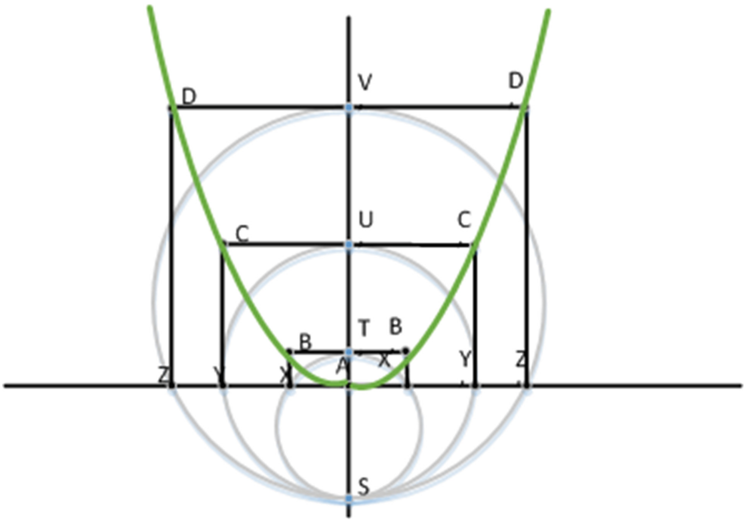

Fig. 1. Design of parabola with help of circles

Knowing how to construct parabola with help of this method we came to idea to present the TCP response function in the same manner. We have analyzed HSTCP [8] in details and have decided instead to use equation of line at log log scale for known two points defined with congestion window value (cwnd, w) and packet drop rate (p) to construct function of parabola uniquely defined with known three points.

We have named this protocol 5G-TCP and have decided to keep the predefined switch point used by HSTCP defined with w = 38 and p = 10^{-3}. In order to construct parabola we have used the following points w1 = 8300 pkt and p1 = 10^{-4} (corresponds at speed of 1 Gbps), w2 = 830000 pkt and p2 = 10^{-7} (corresponds at speed of 100 Gbps), w3 = 3330000 and p3 = 10^{-12} (corresponds at speed of 400 Gbps). These points are chosen because 1 Gbps is expected to be common data transfer rate of 5G mobile networks, 100 Gbps is expected to be backhaul link speed and 400 Gbps is the theoretical speed of optical link defined with IEEE P802.3bs standard. If we have this standardization in mind then we can decade to use future 5G network packet loss probability values and data rates to define our switch points.

Recall that suggested bit error probabilities are real if we use 1500 byte packets. We have tried with these predefined points to calculate the constant distance SA and to use it to plot the parabola function with help of one point tangent circles. Knowing that the process can be translated in algorithm that can calculate next cwnd value was promising until we found that with this set of points we obtain different SA values mainly because the chosen points define the function f1 presented at Fig. 2 which does not corresponds with the one presented at Fig. 1. After we have obtained the result we decided to use the standard parabola equation to define f1 graphically and analytical with help of (1) or (2).

$$y = ax^2 + bx + c \tag{1}$$

$$\log(w) = a(\log(p))^2 + b\log(p) + c \tag{2}$$

y represents log (cwnd) and x is written as log(p). For known three points (defined with w, p; w2, p2 (100 Gbps) and w3, p3 (400 Gbps)) we can unique define function of parabola and if we solve the system of three equations we will define the values of a, b and c. Following values were calculated a = −0.108, b = −2.17 and c = −3.96 which define the function f1 presented at Fig. 2 We have calculated the values of a = −0.41, b = −5.21 and c = −10.47, case when the points of interest are (w, p), (w1, p1) and (w2, p2) that construct f2 which cuts f1 at point B.

Obtained functions f1 and f2 are not adequate to be used mainly because for very small values of p ($p < 10^{-12}$ case when f1 is used and $p < 10^{-7}$ case when f2 is used) cwnd value starts to drop which is not desired. We have decided to solve the system of equations once more but this time for points that correspond at speed of 5 Mbps when p = 10^{-3}, 10 Mbps when p = 10^{-4} and 100 Mbps with p = 10^{-5}. Following parameter values were calculated a = 0.325, b = 1.92, c = 4.42 which define the third function f3 presented at Fig. 2. f3 cuts f1 in point A when cwnd corresponds at rate of 53 Gbps (w4) and p4 = $10^{-6.58}$. We found that f3 can be constructed and plotted with help of the method described above. We have plotted two additional functions with help of the equation of line, case when cwnd corresponds at rate of 400 Gbps, f4 and f5 which cut f1 at different p values, the first one in point C (p5 = 10^{-8})and the other one in point D (p6 = 10^{-12}).

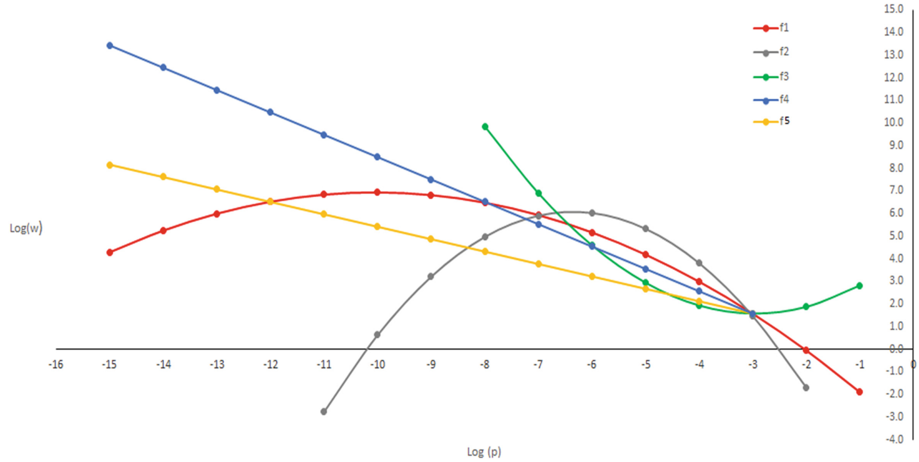

Fig. 2. Graphical presentation of f1, f2, f3, f4, f5

From Fig. 2 we conclude that the response function choice can be improved. Final 5G-TCP response function is defined with f3 when w < cwnd < w4 and p4 < p < p, when w4 < cwnd < w5 and p5 < p < p4 the protocol will use f1 as a response function. For values larger than w5 or when p is smaller or equal than p5 the protocol will use the function f4. The equation of line can be easily transformed from log domain but this does not stand for the equation of parabola. It is important to note that this protocol uses different response functions for low and high speed data rates which make it TCP friendly. Standard parabola is defined with:

$$x^2 = ky \tag{3}$$

or with

$$x^2 = y \tag{4}$$

In log log scale we will have

$$\log(p)^2 = \log(w) \tag{5}$$

$$\log(p) = \frac{\log(w)}{\log(p)} \equiv \log_p(w) \tag{6}$$

$$w = p^{\log(p)} \tag{7}$$

In the case when Eq. (3) is used we will have

$$w = p^{\log(p)^{\frac{1}{k}}} \tag{8}$$

If we plot Eq. (7) we will obtain the representation at Fig. 3 from where it is clear that for very small values of p, w enlarges its value and asymptotically nears the y axis. We can say that the Eqs. (7) and (8) define the 5G-TCP response function α is calculated as in [8], while β can be described with parabola function passing through 0.1 when w = 3330000, p = 10^{-12}; 0.5 when w = 38 and p = 10^{-3}; 0.4 when w = 833 pkt (100 Mbps).

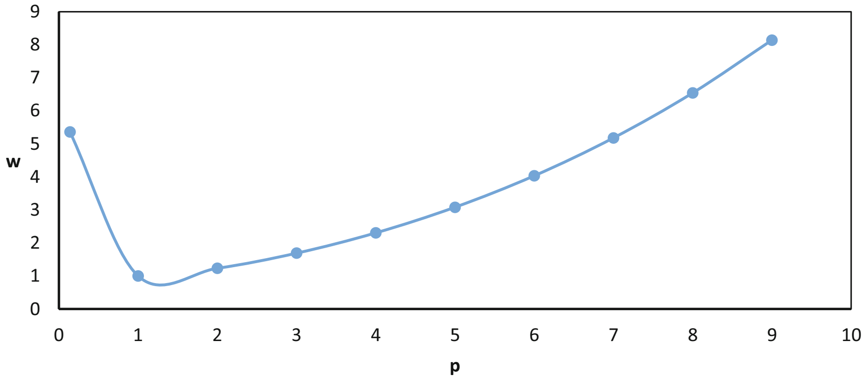

Fig. 3. Graphical presentation of Eq. (7)

For cwnd values larger that 3330000 pkt β will be calculated according equation of line defined with given two points w and w3.

$$\beta(w) = (0.1 - 0.5)\frac{\log(w) - \log(38)}{\log(3330000) - \log(38)} + 0.5 \tag{9}$$

Following values were calculated for a = −.003, b = −0.05 and c = 0.59. We will obtain similar results if we use Eq. (9) to calculate $\beta(w)$. It is important to note that variance during $\beta(w)$ calculation is noticed for lower cwnd values so we advice parabola function to be used in that case.

3 Simulation Scenario

The simulation scenario is presented at Fig. 4, analysis is conducted in order to justify the 5G-TCP design. We use the network simulator (ns2) upgraded with 5G-TCP module. At Fig. 6 we have presented communication of mobile terminal with base station and backhaul high speed link connected with adequate network gateway.

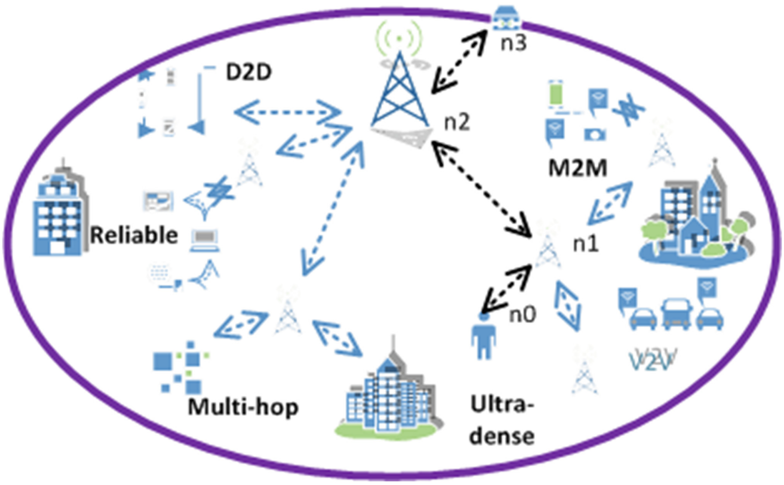

Fig. 4. Simulation scenario. We define wireless medium between n0 and micro base station n1. n1 is wirelessly connected with macro base station n2 and optical link n2–n3 is defined between the macro base station n2 and the network gateway n3

Parameter of interest is the congestion window size variation. Cwnd is directly related with the achieved throughput. Packet size is set at 1500 bytes. Simulation run is 2000 s. Buffers are Drop Tail; buffer size is set at 100% of the product of bottleneck capacity by the largest RTT divided by packet size. The result is presented at Fig. 5. Where we present w as a function of time. It can be noticed that Reno protocol has smallest window growth which directly impacts the throughput that can be achieved when this protocol is used. HSTCP cwnd change compared with Reno is more than

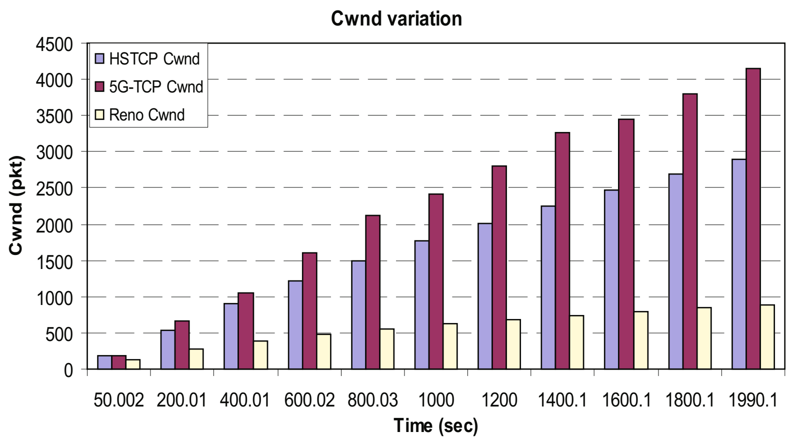

Fig. 5. Congestion window (cwnd) change for Gbps mobile connections with adequate buffer sizes of 8300, 83000 and 166000 packets.

doubled over the time. 5G-TCP presents improved results when compared with HSTCP for sessions longer than 50 s. As we have described in the previous section 5G-TCP employs fast growing function that makes it superior.

4 Conclusion

In this paper we have presented new high speed TCP algorithm with help of detail analysis of HSTCP design. Increased friendliness and higher data rates are achieved when 5G-TCP is employed in predefined simulation environment. The protocol is defined to be used in the future 5G data networks regardless of the engaged MAC Layer. It is defined with several response functions for variety of speeds up to 400 Gbps. For sure the development of high speed protocols that will follow the 5G network capacity is essential in order the end user to experience the network capacity benefit. 5G-TCP represents high speed protocol that uses parabola in order to define the protocol response function and the calculation of β(w) parameter. 5G-TCP should provide efficient usage of the network capacity up to speed of 400 Gbps.

References

1. Duke, M., Braden, R., Eddy, W., Blanton, E., Zimmermann, A.: A roadmap for Transmission Control Protocol (TCP). Internet Engineering Task Force (IETF), RFC7414, February 2015
2. Janevski, T.: Internet Technologies for Fixed and Mobile Networks. Artech House, USA (2015)
3. Rodriguez, J.: Fundamentals of 5G Mobile Networks. Wiley, UK (2015)
4. Ge, X., Cheng, H., Guizani, M., Han, T.: 5G wireless backhaul networks: challenges and research advances. IEEE Netw. **28**(6), 6–11 (2014)
5. Janevski, T.: NGN Architectures, Protocols, and Services. Wiley, UK (2014)
6. Gunduz, D., Stamatiou, K., Michelusi, N., Zorzi, M.: Designing intelligent energy harvesting communication systems. IEEE Commun. Mag. **52**(1), 210–216 (2014)
7. Kelly, T.: Scalable TCP: improving performance in highspeed wide area networks. Comput. Commun. Rev. **32**(2), April 2003
8. Floyd, S.: HighSpeed TCP for large congestion windows. RFC 3649 (2003)
9. Xu, L., Harfoush, K., Rhee, I.: Binary increase congestion control for fast, long distance networks. In: Proceedings of the IEEE INFOCOM, vol. 4, pp. 2514–2524, March 2004
10. Leith, D.: H-TCP: TCP congestion control for high bandwidth-delay product paths. IETF Internet Draft (2008). http://tools.ietf.org/html/draftleith-tcp-htcp-06
11. Rhee, I., Xu, L.: CUBIC: a new TCP-friendly high-speed TCP variant. SIGOPS Oper. Syst. Rev. **42**(5), 64–74 (2008)
12. Marfia, G., Palazzi, C., Pau, G., Gerla, M., Sanadidi, M., Roccetti, M.: TCP Libra: Exploring RTT-Fairness for TCP. UCLA Computer Science Department, Technical Report UCLA-CSD TR-050037 (2005)
13. Caini, C., Firrincieli, R.: TCP Hybla: a TCP enhancement for heterogeneous networks. Int. J. Satell. Commun. Network. **22**, 547–566 (2004)
14. Baiocchi, A., Castellani, A.P., Vacirca, F.: YeAH-TCP: yet another highspeed TCP. In: Proceedings of the PFLDnet, ISI, Marina Del Rey (Los Angeles), California, February 2007