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Performance Enhancement of TCP Using ECN and Snoop Protocol for Wi-Max Network

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ABSTRACT
Providing Internet services over wireless links has grown rapidly in recent years. TCP (Transmission Control Protocol) has been performing well over the traditional wired networks where packet losses occur mostly because of congestion, it cannot react efficiently in wireless networks, which suffer from significant non-congestion-related losses due to reasons such as bit errors and handoffs. The paper shows how Explicit Congestion Notification (ECN), Snoop protocol and their combination can be used to improve the performance of TCP in Wi-Max network, ECN will help in congestion control and SNOOP will retransmit the packets that are lost from nodes in between, saving nearly half the retransmission time and avoiding the decreasing in transmission speed. This paper investigates the performance of above mentioned protocols over Wi-Max wireless scenario which improves the various parameters of TCP such as throughput. The results of the same can be demonstrated on NS2 simulator (Wi-Max module ns–nist-wimax.tgz).

Keywords:
Explicit Congestion Notification (ECN) Transmission Control Protocol (TCP), Snoop Protocol, Network Simulator (NS).

1. INTRODUCTION

1.1 Transmission Control Protocol (TCP)
The Transmission Control Protocol is one of the core protocols of the Internet Protocol Suite. TCP is so central that the entire suite is often referred to as "TCP/IP." Whereas IP handles lower-level transmissions from computer to computer as a message makes its way across the Internet. When IP is transmitting data on behalf of TCP, the content of the IP packet body is TCP payload. Due to network congestion, traffic load balancing, or other unpredictable network behavior, IP packets can be lost or delivered out of order. TCP detects these problems, requests retransmission of lost packets, rearranges out-of-order packets, and even helps minimize network congestion to reduce the occurrence of the other problems [2]. Once the TCP receiver has finally reassembled a perfect copy of the data originally transmitted, it passes that datagram to the application program. Thus, TCP abstracts the application's communication from the underlying networking details.

1.2 TCP over wireless
TCP has been optimized for wired networks. Any packet loss is considered to be the result of congestion and the congestion window size is reduced dramatically as a precaution. However, wireless links are known to experience sporadic and usually temporary losses due to fading, shadowing, hand off, and other radio effects, that cannot be considered congestion. After the (erroneous) back-off of the congestion window size, due to wireless packet loss, there can be a congestion avoidance phase with a conservative decrease in window size.

1.3 Congestion control
The main aspect of TCP is congestion control. TCP uses a number of mechanisms to achieve high performance and avoid 'congestion collapse', where network performance can fall by several orders of magnitude. These mechanisms control the rate of data entering the network, keeping the data flow below a rate that would trigger collapse. Acknowledgments for data sent, or lack of acknowledgments, are used by senders to infer network conditions between the TCP sender and receiver. Coupled with timers, TCP senders and receivers can alter the behavior of the flow of data. This is more generally referred to as congestion control and/or network congestion avoidance. In addition, senders employ a retransmission timer that is based on the estimated round-trip time (or RTT) between the sender and receiver, as well as the variance in this round trip time. There are subtleties in the estimation of RTT. Enhancing TCP to reliably handle loss, minimize errors, manage congestion and go fast in very high-speed environments are ongoing areas of research and standards development. As a result, there are a number of TCP congestion avoidance algorithm variations ie TCP New Reno & Random Early Detect (RED). TCP New Reno improves retransmission during the fast recovery phase of TCP Reno. Random Early Detect is a congestion avoidance mechanism implemented in routers that work on the basis of active queue management. RED addresses the shortcomings of TailDrop.

1.4. Explicit Congestion Notification (ECN)
Explicit Congestion Notification is an extension to the Internet Protocol. ECN allows end-to-end notification of network congestion without dropping packets [1],[2]. Traditionally, TCP/IP networks signal congestion by dropping packets. When ECN is successfully negotiated, an ECN-aware router may set a bit in the IP header instead of dropping a packet in order to signal the beginning of congestion. The receiver of the packet echoes the congestion indication to the sender, which must react as though a

packet drop were detected. ECN uses two bits in the Differentiated Services field in the IP header.

Operation of ECN with TCP: In addition to the two ECN bits in the IP header, TCP uses two flags in the TCP header to signal the sender to reduce the amount of information it sends. These are the ECN-echo and Congestion Window Reduced bits. Use of ECN on a TCP connection is optional; for ECN to be used, it must be negotiated at connection establishment by including suitable options in the SYN and SYN-ACK segments. When ECN has been negotiated on a TCP connection, the sender marks all data segments with the ECN-capable codepoint. A router that detects impending congestion may choose to mark an ECN-capable packet with the congestion experienced codepoint rather than dropping it outright. Upon receiving a TCP segment with the Congestion Experienced codepoint, the TCP receiver sends an acknowledgement with the ECN-echo flag set. The ECN-echo bit indicates congestion to the sender, which reduces its congestion window as for a packet drop. It then acknowledges the congestion indication by sending a segment with the Congestion Window Reduced codepoint.

Effects on performance: Since ECN is only effective in combination with an Active Queue Management (AQM) policy, the benefits of ECN depend on the precise AQM being used. A few observations, however, appear to hold across different AQMs. As expected, ECN reduces the number of packets dropped by a TCP connection, which, by avoiding a retransmission, reduces latency and especially jitter. This effect is most drastic when the TCP connection has a single outstanding segment, when it is able to avoid an RTO timeout. Effects of ECN on bulk throughput are less clear, due to the fact that modern TCP implementations are fairly good at resending dropped segments in a timely manner when the sender's window is large. Use of ECN has been found to be detrimental to performance on highly congested networks when using AQM algorithms that never drop packets. Modern AQM implementations avoid this pitfall by dropping rather than marking packets at very high load.

1.5. SNOOP Protocol

The Snoop Protocol [3] was designed to solve the burst/intermittent packet loss due to high bit error rates and short temporary disconnections experienced by TCP in wireless link. The Snoop agent is designed to reside on the router between the wired and wireless link, referred to as the gateway, or base station (BS).The role of the snoop agent is to monitor the TCP packets transmitted from a fixed host to a mobile host and vice versa. The agent caches all those packets locally and in the case of receiving duplicate acknowledgments (ACKs), retransmits the packets promptly and suppresses duplicate ACKs. The Snoop protocol performs retransmission of lost packets locally (at the base station) and hence avoids lengthy fast retransmission and congestion control at the sender side. By this method, end-to-end semantics of TCP is maintained and performance of TCP is improved [12]. The snoop module maintains a cache of TCP packets sent from the fixed host that haven't yet been acknowledged by the mobile host. When a new packet arrives from the fixed host, the snoop module adds it to its cache and passes the packet on to the routing code, which performs the normal routing functions. The snoop module also keeps track of all the acknowledgments sent from the mobile host. When a packet loss is detected (either by the arrival of a duplicate acknowledgment or by a local timeout), it retransmits the lost packet to the mobile host if it has the packet cached. Thus, the base station (snoop) hides the packet loss from the fixed host by not propagating duplicate acknowledgments, thereby preventing unnecessary congestion control mechanism invocation. Snoop protocol is a cross layer design protocol i.e. transport aware link layer protocol [11].

2. IMPLEMENTATION OF ECN & SNOOP PROTOCOL.

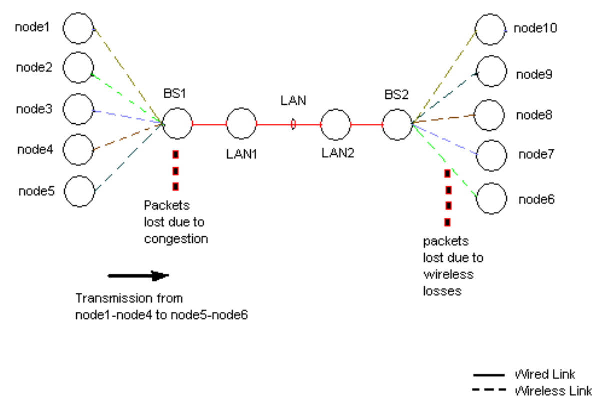

Figure 1. Wi-Max unidirectional Scenario.

Scenario in figure 1 is a Wi-Max unidirectional network. It consists of 14 nodes of which 2 are wired cum wireless node that are base stations BS1 and BS2, 10 are wireless nodes , 2 are LAN nodes. The LAN is of 100 Mbps. LAN may be implemented with snooping agent. LAN nodes are connected to base station with a 500kbps 10msec RED bidirectional link. RED link is for marking the packets in case congestion occurs. Wireless connection is of 256Mbps.Wireless nodes 1 to 5 are sending data to wireless nodes 6 to 10. The protocol used is TCP. It is attached with a File Transfer Protocol (FTP). The wireless routing protocol used is DSDV (Destination Sequence Distance Vector). All the nodes start transmission simultaneously leading to congestion in base station 1(BS1).Also wireless loss are introduced between base station 2 (BS2) and wireless nodes 6 to 10.

At first the ECN is disabled and there is no snooping agent in the LAN network. The limit of Q-length is set to 50. If the Q-length is full the packets will be dropped. When transmission starts there will be congestion at BS1 and it will start dropping packets in order to notify transmitting nodes of congestion which will then apply the congestion control algorithm to stop it(i.e. the transmitting nodes will reduce there speed to half). At BS2 there will be packet drop due to wireless loss. TCP will consider these packet drops also as packet dropped due to congestion (as TCP was basically developed as a protocol for wired network in which all the packet drop is considered to be due to congestion). It responds to these packet drops by reducing it speed which is not necessary, as reducing the speed in this case will reduce the throughput. Thus the performance of TCP over wireless network is poor.

Next ECN is enabled keeping rest of the network same. Again there is a possibility of congestion at BS1. But now instead of dropping packet to notify the user of congestion the BS1 will start marking packet before the congestion takes place. A lower threshold is set in ECN as soon as this threshold is crossed the BS1 starts marking packets. It must be noted the congestion has not actually occurred. Now with marked packets symbolizing congestion the transmitting nodes will respond to them by adjusting there transmission speed accordingly avoiding congestion. There will be packet drop at BS2 due to wireless loss but with ECN enabled they won't be considered as packet drop due to congestion and transmission speed will not be affected. Thus ECN helps in improving TCP's performance over wireless network by not allowing congestion to occur.

The snooping agent is enabled in the LAN and ECN is disabled. There will be congestion at BS1 and it will drop packets to symbolize congestion. TCP will take the required steps to stop it. Next there will be packet drop due to wireless loss. When the duplicate ACK of packet drop reaches the LAN it does not pass the duplicate acknowledgement to transmitter but itself retransmits that lost packet. Thus TCP will not consider that as congestion also the transmission speed will not be affected and retransmission time will be less. In this way the snooping agent of LAN will help improve performance of TCP in wireless network.

In order to further improve the performance of TCP we enable both ECN and Snooping agent simultaneously in the network shown in figure 1. Using both we have advantages of both, with ECN enabled congestion is avoided also the retransmission time of packets that were lost due to wireless loss will be minimized with snooping agent transmitting them for the LAN node itself and transmitters not required to send packets again. Thus the performance of ECN and SNOOP both enabled the performance improved the performance of TCP as can be seen from the graphs below.

3. RESULT AND ANALYSIS OF UNIDIRECTIONAL WI-MAX NETWORK

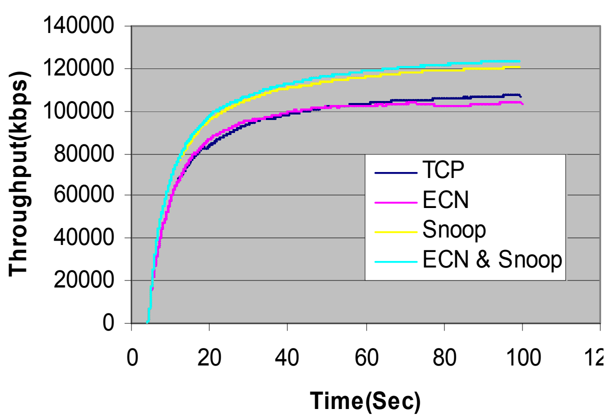

Figure 2. Throughput Vs Time.

Figure 2 shows the graph of Throughput Vs Time of the Network. The throughput plot shows there is substantial improvement in the performance of TCP over wireless networks when we apply both ECN and SNOOP. The throughput is maximum for ECN and SNOOP both applied followed by SNOOP then TCP and ECN.

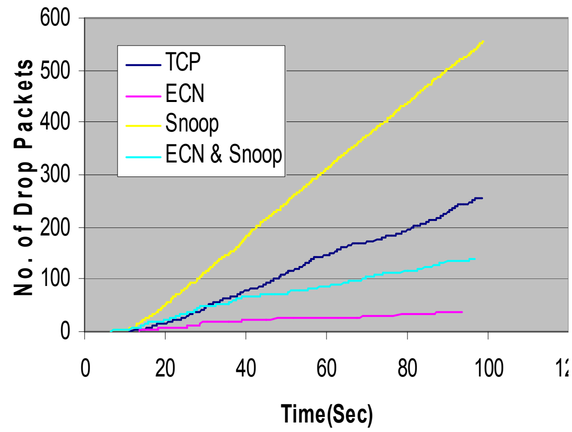

Figure 3. Drop packets Vs Time.

Figure 3 shows the analysis of the drop packets Vs Time.

Drop packets are the least for ECN. The drop packets in case of SNOOP are maximum. The drop packets in case of ECN and SNOOP both applied are less as compared to TCP but more than ECN. This is because congestion is increased to some extent when SNOOP is applied.

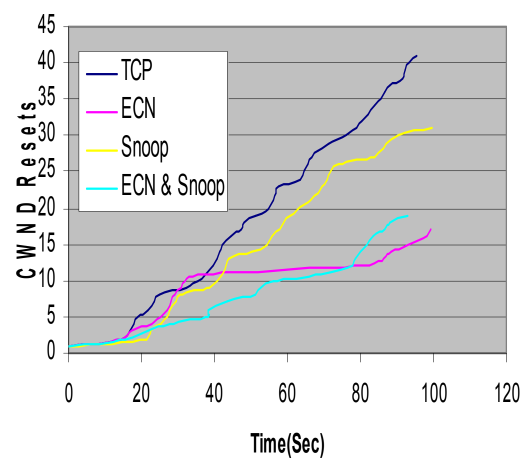

Figure 4. Congestion Window Resets Vs Time.

Figure 4 shows the analysis of CWND reset Vs Time.

Congestion window resets are maximum for TCP which is not desirable for better performance. The resets are almost same and minimum in case of ECN, and ECN & Snoop both applied.

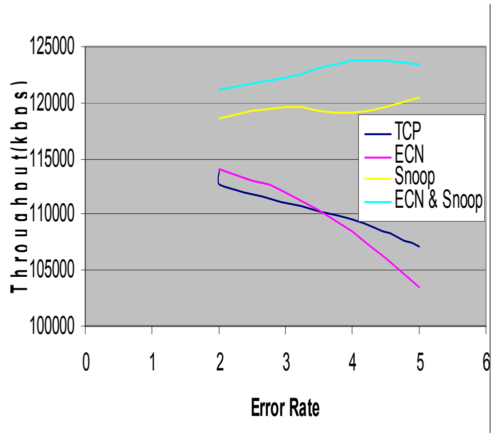

Figure 5. Throughput Vs Error Rate

The above graph indicates that the performance of ECN and SNOOP both applied with increasing error rate is best amongst the four. Its throughput remains nearly same for increasing error rate. The throughput of TCP and ECN degrade substantially with increase in error rate.

4. WI-MAX NETWORK (BIDIRECTIONAL)

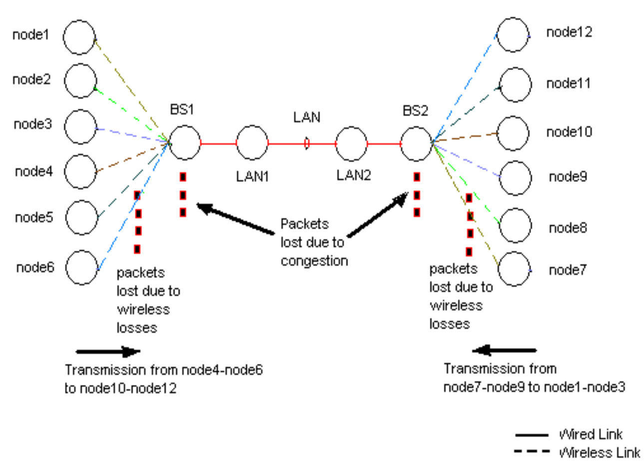

Figure 6. Wi-Max bidirectional Scenario

Scenario in figure 6 is a WIMAX bidirectional network. It consists of 16 nodes of which 2 are wired cum wireless node that are base stations (BS1) and (BS2) ,2 are LAN nodes. The LAN is of 100 Mbps. LAN can be implemented with snooping agent. LAN nodes are connected to base station with a 500kbps, 10msec delay RED bidirectional link. RED link is for marking the packets in case congestion occurs. Wireless connection is of 256Mbps. Wireless nodes 4 to 6 are sending data to wireless nodes 10 to 12 & wireless nodes 7 to 9 are sending data to wireless nodes 1 to 3. The protocol used is TCP. It is attached with a File Transfer Protocol (FTP). The wireless routing protocol used is DSDV (Destination Sequence Distance Vector). The limit of Q-length is set to 50. If the Q-length is full the packets will be dropped. All the nodes start transmission simultaneously leading to congestion in base station 1(BS1) and base station 2(BS2). Also wireless loss is introduced between BS2 and wireless nodes 7 to 12 and BS1 and wireless nodes 1 to 6.

First, ECN is disabled and there is no snooping agent in the LAN network. When transmission starts there will be congestion at both the base stations and it will start dropping packets in order to notify transmitting nodes of congestion which will then apply the congestion control algorithm to stop it(i.e. the transmitting nodes will reduce there speed to half). Between the wireless links there will be packet drop due to wireless loss. TCP will consider these packet drops also as packet dropped due to congestion. It responds to these packet drops also by reducing it speed which is not necessary, as reducing the speed in this case will reduce the throughput. Thus the performance of TCP over wireless network is degraded.

ECN is enabled keeping rest of the network same. Again there is a possibility of congestion at both BS1 & BS2. But now instead of dropping packet to notify the user of congestion the BS1 & BS2 will start marking packet before the congestion takes place. A lower threshold is set in ECN as soon as this threshold is crossed the BS1 & BS2 starts marking packets. It must be noted the congestion has not actually occurred. Now with marked packets symbolizing congestion the transmitting nodes will respond to them by adjusting there transmission speed accordingly avoiding congestion. There will be packet drop in between wireless links due to wireless loss but with ECN enabled they won't be considered as packet drop due to congestion and transmission speed will not be affected. Thus ECN helps in improving TCP's performance over wireless network first by not allowing congestion to occur second it is able to differentiate between packet drop due wireless loss.

The snooping agent is enabled in the LAN and ECN is disabled. There will be congestion at BS1 &BS2 and it will drop packets to symbolize congestion. TCP will take the required steps to stop it. Next there will be packet drop due to wireless loss. When the duplicate ACK of packet drop reaches the LAN it does not pass the duplicate acknowledgement to transmitter but itself retransmits that lost packet. Thus TCP will not consider that as congestion also the transmission speed will not be affected and retransmission time will be less. In this way the snooping agent of LAN will help improve performance of TCP in wireless network.

In order to further improve the performance of TCP both ECN and Snooping agent are enabled simultaneously in the Wi-Max network. Using both we have advantages of both, with ECN enabled congestion is avoided also the retransmission time of packets that were lost due to wireless loss will be minimized with snooping agent transmitting them for the LAN node itself and transmitters not required to send them again. Thus the performance of ECN and SNOOP both enabled the performance is improved as can seen from the graphs below.

5. RESULT AND ANALYSIS OF BI-DIRECTIONAL WI-MAX NETWORK

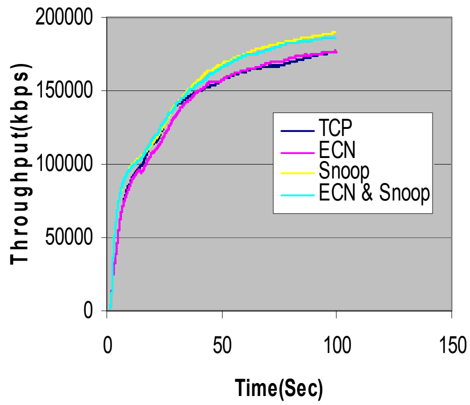

Figure 7. Throughput Vs Time.

The graph shows the throughput of SNOOP is nearly equal to throughput of ECN and SNOOP both applied and that it is greater than throughput of ECN and TCP which are nearly equal. This is because the capacity of base station in case of WiMax is much greater than WiFi, hence congestion is not a problem in WiMax but it may be evident if the number of nodes are increased.

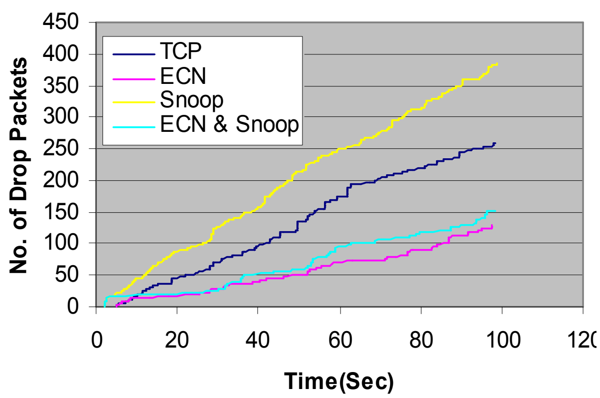

Figure 9. Drop packets Vs Time.

Drop packets are the least for ECN. The drop packets in case of SNOOP are maximum. The drop packets in case of ECN and SNOOP both applied are less as compared to TCP. Even though the drop packets are marginally more than ECN, for ECN and SNOOP both applied, but the good put is better for ECN and SNOOP combined as the throughput is more as compared to ECN.

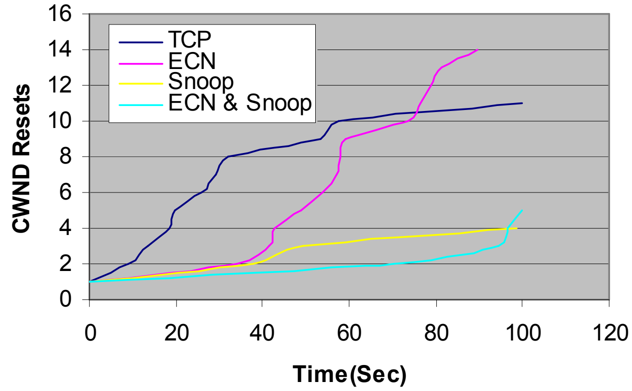

Figure 9. Congestion Window Resets Vs Time.

Congestion window resets are maximum for both ECN and TCP. The resets are minimum in case of SNOOP. The resets in case of ECN and SNOOP both applied and SNOOP are nearly same.

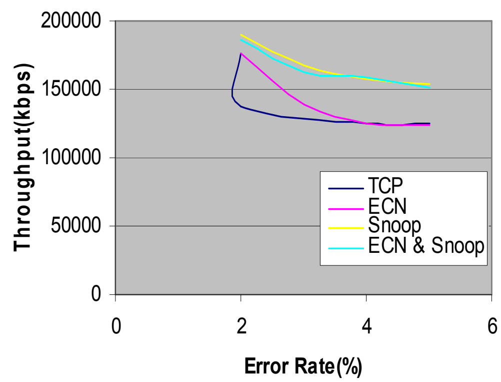

Figure 10. Throughput Vs Error Rate.

The above graph indicates that the performance of ECN and SNOOP both applied with increasing error rate is best amongst the four. Its throughput remains nearly same for increasing error rate. The throughput of TCP and ECN degrade substantially with increase in error rate.

6. CONCLUSION

The analysis of the result in NS-2 simulator shows improvement in the performance of TCP by improving overall throughput which is better in the Wi-Max (Wi- Max module ns–nist-wimax.tgz, patch ns-2.31-04170. is available in NS [14]) scenarios for ECN and SNOOP combined than individual TCP, ECN or SNOOP. Also the drop packets are reduced and so are congestion window resets. The throughput Vs error rate graph also shows the performance of ECN and SNOOP combined is better in the two scenarios. From all the analysis (i.e. analyzing all the four parameters from each scenario) we conclude that in order to improve the performance of TCP over wireless network both ECN and SNOOP should be applied simultaneously. ECN will help in congestion control and SNOOP will retransmit the packets that are lost from nodes in between, saving nearly half the retransmission time and avoiding the decreasing in transmission speed and an optimum transmission performance in a wireless network can be achieved.

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