SURVEY: TCP PERFORMANCE ANALYSIS AND ISSUES OVER MOBILE AD HOC NETWORKS

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Abstract: *Wireless Ad-Hoc networks are usually defined as an autonomous system of nodes connected by wireless links and communicating in a multi-hop fashion. The benefits of ad-hoc networks are many, but the most important one is their ease of deployment without centralized administration or fixed infrastructure, thereby enabling an inexpensive way to achieve the goal of ubiquitous communications. One of the fundamental tasks that an ad hoc network should often perform is congestion control. It is a mechanism by which the network bandwidth is distributed across multiple end-to-end connections. Its main objective is to limit the delay and buffer overflow caused by network congestion and provide tradeoffs between efficient and fair resource allocation. If we use TCP protocol over ad-hoc network, then it does not perform well because it was designed for the infrastructure network. Performance of TCP significantly degrades in wireless ad hoc networks due to high bit error rates, frequent route changes, and partitions etc. A lot of work has been done to improve TCP performance over mobile ad hoc networks. In this paper, we will review the TCP protocol performance and issues over wireless ad-hoc network, its congestion control methods and various solutions provided by other researchers.*

***Keywords:** Congestion Control**,** MANET, Protocol, TCP, Wireless mobile ad-hoc networks*

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1. INTRODUCTION

A MANET consists of mobile nodes, a router with multiple hosts and wireless communication devices. The wireless communication devices are transmitters, receivers and smart antennas. These antennas can be of any kind and nodes can be fixed or mobile. The term node referred to as, which are free to move arbitrarily in every direction. These nodes can be a mobile phone, laptop, personal digital assistance and personal computer. These nodes can be located in cars, ships, airplanes or with people having small electronic devices. Nodes can connect each other randomly and forming arbitrary topologies. Nodes communicate to each other and also forward packets to neighbor nodes as a router. The ability of self configuration of these nodes makes them more suitable for urgently required network connection [1].

Salient characteristics of Mobile Ad-Hoc Network:

1. **Dynamic topologies:** Nodes are free to move arbitrarily; thus, the network topology--which is typically multi-hop--may change randomly and rapidly at unpredictable times, and may consist of both bidirectional and unidirectional links. [1]**.**
2. **Bandwidth-constrained**: Wireless links will continue to have significantly lower capacity than their hardwired counterparts. In addition, the realized throughput of wireless communications—after accounting for the effects of multiple access, fading, noise, and interference conditions etc.--is often much less than a radio's maximum transmission rate. One effect of the relatively low to moderate link capacities is that congestion is typically the norm rather than the exception, i.e. aggregate application demand will likely approach or exceed network capacity frequently. As the mobile network is often simply an extension of the fixed network infrastructure, mobile ad hoc users will demand similar services. These demands will continue to increase as multimedia computing and collaborative networking applications rise [4].
3. **Energy-constrained operation:** Some or all of the nodes in a MANET may rely on batteries or other exhaustible means for their energy. For these nodes, the most important system design criteria for optimization may be energy conservation.[7]
4. **Limited physical security:** Mobile wireless networks are generally more prone to physical security threats than are fixed- cable nets. The increased possibility of eavesdropping, spoofing, and denial-of-service attacks should be carefully

considered. Existing link security techniques are often applied within wireless networks to reduce security threats. As a benefit, the decentralized nature of network control in MANETs provides additional robustness against the single points of failure of more centralized approaches. [1][2]

TCP Protocol

The Transmission Control Protocol (TCP) is intended for use as a highly reliable host-to-host protocol between hosts in packet-switched computer communication networks, and in interconnected systems of such networks.

TCP consists of a set of rules: for the protocol, that are used with the Internet Protocol, and for the IP, to send data "in a form of message units" between computers over the Internet. While IP handles actual delivery of the data, TCP keeps track of the individual units of data transmission, called segments, that a message is divided into for efficient routing through the network. For example, when an HTML file is sent from a Web server, the TCP software layer of that server divides the sequence of octets of the file into segments and forwards them individually to the IP software layer (Internet Layer). The Internet Layer encapsulates each TCP segment into an IP packet by adding a header that includes (among other data) the destination IP address. Even though every packet has the same destination address, they can be routed on different paths through the network. When the client program on the destination computer receives them, the TCP layer (Transport Layer) reassembles the individual segments and ensures they are correctly ordered and error free as it streams them to an application.[1][20][21]

TCP Congestion

Main aspect of TCP protocol 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. They also yield an approximately max-min fair allocation between flows. Modern implementations of TCP contain four intertwined algorithms: Slow-start, congestion avoidance, fast retransmit, and fast recovery .[1][20]

TCP performance over Ad hoc network

Unique features of ad hoc networks seriously deteriorate TCP performance. These features include the unpredictable wireless channels due to fading and interference, the vulnerable shared media access due to random access collision, the hidden terminal problem and the exposed terminal problem, and the frequent route breakages due to node mobility. All of these pose great challenges on TCP to provide reliable end-to-end communications in mobile ad hoc networks. These challenges can be broken down into five categories, i.e., the channel error, the medium contention and collision, the mobility, the multi-path routing and congestion, whose adverse impacts on TCP is elaborated below in sequence.[1]

TCP does not perform well due to the following reasons:

1. **Misinterpretation of packet loss:** Traditional TCP was designed for wired network where packet loss is mainly attributed to network congestion. It is detected by sender's packet RTO period. Once packet loss is detected, sender assumes congestion in network and starts congestion control scheme. In Ad hoc networks, there may be packet loss due to different factors such as high bit error rate in channel, collisions at MAC layer, collisions due to hidden and exposed terminal, location independent contention, frequent path break due to mobility etc.
2. **Misinterpretation of congestion window:** TCP uses a congestion window which controls the transmission rate. In ad hoc network, congestion control scheme is invoked when ever there is a path break. This increase the RTO period and reduces the congestion window. When route is reestablished, the congestion window may not reflect the transmission rate acceptable to new route, as the new route may actually accept a higher transmission rate. Hence, in case of frequent path breaks, congestion window may not reflect the maximum transmission rate acceptable to network.
3. **Multi-path Routing:** Routes are short-lived due to frequent link breakages. To reduce delay due to route re-computation, some routing protocols such as the Temporally-Ordered Routing Algorithm (TORA) maintain multiple routes between a sender-receiver pair and use multi-path routing to transmit packets. In such a case, packets coming from different paths may not arrive at the receiver in order. Being unaware of multi-path routing, TCP receiver would misinterpret such out-of-order packet

arrivals as congestion. The receiver will thus generate duplicate ACKs that cause the sender to invoke congestion control algorithms like fast retransmission (upon reception of 3 duplicate ACKs).

4. **Path Length and asymmetric link behavior:** Probability of path break increase with path length which can degrade the network performance. There may be uni-directional or bi-directional links. Directional links can deliver the packet to the receiver but can not ensure the delivery of ACK to the sender because it is possible that bi-directional link can be changed to uni-directional link, due to the change in topology. This can lead the TCP to invoke congestion control algorithm.
5. **Network partitioning and remerging:** Mobility can cause the network partitioning. Due to dynamical topological change, network gets partitioned and after partitioning, sender and receiver may fall in different partitions and intermediate nodes in another partition. This change will lead to the path break.

Versions of TCP protocol

There are different versions of TCP protocol: TCP Tahoe, TCP Reno, NewReno, SACK and Vegas. Reno algorithm which bases on loss detection is widely used in Internet, while TCP Vegas adjusts transmission rate basing on RTT of packets. Although Vegas is improved in every aspect, when it coexists with Reno, it can not share bandwidth fairly. Precise estimation of RTT is important for improving the performance of TCP Vegas.[21]

TCP enhancements to work with ad hoc networks

1. **TCP-F:** TCP-F provides a simple feedback based solution to minimize the problem of frequent path breaks and it also offers the congestion control method. It depends upon the intermediate node's ability to detect the route failure and routing protocol's capability to reconfigure the broken path with in short duration.[1][11][12]
2. **TCP-ELFN:** It improves the performance by using explicit link failure notification. It requires only link failure notification about path break. It does not perform well, if path breaks are last longer and if the congestion window fails to reflect the acceptable transmission rate to the network and the sender.[1][13][14]
3. **TCP-BuS:** It includes the avoidance of fast retransmission due to the use of buffering, sequence numbering, and selective acknowledgement. It also utilize the

capabilities of on demand routing protocols such as ABR but its dependency over protocol may cause the control over head, buffer over flow and packet loss.[1][15]

4. **ATCP:** It implements a thin layer between IP and TCP (called ATCP) that ensures correct TCP behavior while maintaining high throughput. This is done by putting TCP into persist mode when the network is disconnected or when there are losses due to high bit error. Merits of ATCP are: (a) End-to-end TCP semantics are maintained. (b) ATCP is transparent which means that nodes with and without ATCP can set up TCP connections normally. (c) ATCP's performance is almost ideal as measured by the time to transfer large files. (d) ATCP does not interfere with TCP's congestion control behavior when there is network congestion.[1][16][17]
5. **Split-TCP:** It solves the issues caused by the longer paths. It splits the long TCP connection into set of short TCP connections. Its merits are: Improved the throughput and minimized the impact of mobility but it requires modification of TCP protocol, failure of intermediate nodes can lead to performance degradation. Frequent path failure can affect the performance of Split TCP.[1][18][19]

2. LITERATURE SURVEY

TCP protocol was developed to work with the infrastructure network but when it is used over ad hoc network then its performance is degraded by the behavior of the ad hoc network. Many researchers has given the solution to increase the TCP performance over such networks by modifying the existing working of TCP protocol to achieve their goals.

C. Greco, M. Cagnazzo, and B.P.Popescu [2] addressed the challenge of delivering a video stream, encoded with multiple descriptions, in a mobile ad-hoc environment with low-latency constraints. This kind of application is meant to provide an efficient and reliable video communication tool in scenarios where the deployment of an infrastructure is not feasible, such as military and disaster relief applications. First, they presented a recently proposed protocol that employs a reliable form of one-hop broadcast to build an efficient overlay network according to a multi-objective function that minimizes the number of packets injected in the network and maximizes the path diversity among descriptions. Then, They introduced a cross-layer congestion control strategy where the MAC layer is video-coding aware and adjusts its transmission parameters (namely, the RTS retry limit) via congestion/distortion optimization. The main challenge in this approach is providing a reliable estimation of congestion and distortion, given the limited information available at each node. Results show that, if a stringent constraint of low delay is imposed, our technique grants a consistent gain in terms of both PSNR and delay reduction, for bitrates up to a few megabits per second.

X.M. Zhang, W. B. Zhu, N.N. Li, and D.K. Sung [3] proposed mechanism that focuses on link contentions and does not consider the mobility factor. Link failures due to mobility are part of the main sources of link unreliability in mobile ad hoc networks, which they have previously investigated. In their future work, they will give a comprehensive consideration of these factors to improve the performance of the network. They proposed a novel mechanism called congestion window adaptation through contention detection, which provides a more accurate method of estimating the contention status. Based on this mechanism, They presented a congestion window adaptation method to limit the window size from overshooting. Simulation results show that proposed mechanism outperforms the conventional TCP and the enhanced mechanisms called TCP with contention control and TCP with a maximum window.

Nadim Parvez, Anirban Mahanti, and Carey Williamson [4] presented an analytic model for the bulk data transfer performance of TCP NewReno. The model expresses steady-state throughput in terms of RTT and loss rate. NewReno throughput model has three important features. First, they explicitly model the fast recovery algorithm of TCP NewReno, which is important since a NewReno flow may spend a significant amount of time in the fast recovery phase. Second, they also consider the possibility of incurring a timeout following an unsuccessful fast recovery phase. Third, analytical model uses a flexible two-parameter loss model that captures both the loss event rate, as well as the burstiness of segment losses within a loss event, and thus is able to better capture the dynamics of TCP loss events on the Internet. They validated the model with extensive ns-2 simulation experiments. They also validated the model using a real TCP NewReno implementation. Results show that the proposed model can predict steady-state TCP NewReno throughput for a wide range of network conditions, unlike existing Reno models. The results also illustrate the significant performance advantages of NewReno over Reno in many scenarios because of NewReno's improved fast recovery algorithm.

M. Sepulcre, J.Gozalvez, J.H. arri, and H. Hartenstein [5] proposed a novel proactive congestion control policy for vehicular ad-hoc networks, in which each vehicle's communication parameters are adapted based on their individual application requirements. Contrary to other approaches, where transmission resources tend to be assigned based on system-level performance metrics, the proposed technique aims to individually satisfy the target application performance of each vehicle, while globally minimizing the channel load to prevent channel congestion. The proposed policy has been evaluated considering the lane change assistance application. However, it could be used as the basis of advanced contextual congestion control policies, and congestion control protocols based on the experienced channel load, to efficiently distribute the available bandwidth. Moreover, the proposed approach could be extended to scenarios where multiple applications, each with different requirements, are simultaneously run by the same vehicle. While some applications could require a high packet rate, others could fix the minimum distance at which messages should be received. These requirements will need to be safely combined, which represents a challenging task for the future deployment of VANETs.

Juan J. Jaramillo, R. Srikant and L. Ying [6] studied the problem of scheduling in single-hop wireless networks with real-time traffic, where every packet arrival has an associated deadline and a minimum fraction of packets must be transmitted before the end of the deadline. Using optimization and stochastic network theory they studied the problem of scheduling to meet quality of service (QoS) requirements under heterogeneous delay constraints and time varying channel conditions. Analysis results in an optimal scheduling algorithm which fairly allocates data rates to all flows while meeting long-term delay demands. They also proved that under a simplified scenario our solution translates into a greedy strategy that makes optimal decisions with low complexity.

J. Jose Jaramillo and R. Srikant [7] presented an optimization framework for the problem of congestion control and scheduling of elastic and inelastic traffic in ad hoc wireless networks. The model was developed for general interference graphs, general arrivals, and time-varying channels. Using a dual-function approach, They presented a decomposition of the problem into an online algorithm that is able to make optimal decisions while keeping the network stable and fulfilling the inelastic flow's QoS constraints. studies the problem of congestion control and scheduling in ad hoc wireless networks that have to support a mixture of besteffort and real-time traffic. Optimization and stochastic network theory have been successful in designing architectures for fair resource allocation to meet long-term throughput demands. However, to the best of our knowledge, strict packet delay deadlines were not considered in this framework previously. They proposed a model for incorporating the quality-of-service (QoS) requirements of packets with deadlines in the optimization framework. The solution to the problem results in a joint congestion control and scheduling algorithm that fairly allocates resources to meet the fairness objectives of both elastic and inelastic flows and per-packet delay requirements of inelastic flows.

X.Zhang, J. Lv, X. Han, and D.K. Sung [8] proposed a new mechanism to feed back the real MAC channel efficiency to TCP and compared it with the virtual TCP channel efficiency. They evaluated the performance of the proposed mechanism. Simulation results show that the proposed mechanism outperforms 802.11 DCF in terms of throughput and delay. Comparing the real channel efficiency in MAC protocol with the virtual channel efficiency in TCP, it can adaptively control the transmission rate in TCP by using the congestion window and the flow of TCP ACKs, in order to alleviate the load of MAC protocol before a congestion event occurs and to enhance the network performance. Simulation results show that the proposed mechanism outperforms 802.11 DCF in terms of throughput and delay.

S. Peng, Z. Li, Y. He, and A. Xu [9] analyzed the impact of assembly and burst loss to the performance of TCP over OBS networks. An analytical parameter WDDP is defined, which combines the influencial factors in both of the TCP layer and the OBS layer. The throughputs under different levels of DPs are derived. Both the simulation and analytical results show the same trends. To reduce the WDDP without introducing the extra assembly delay penalty, we proposed a TCP window based flow-oriented DAP algorithm. Through comparing the previous and current burst lengths, DAP can track the variation of the TCP window, and update the assembly period dynamically for the next assembly. Furthermore, DAP can adjust the assembly period dynamically according to the network conditions. A novel OBS ingress edge node architecture is designed for the flow-oriented assembly. The performance of DAP is also evaluated over a single TCP connection and multiple TCP connections, respectively. The simulation results show that DAP performs better than FAP at almost the whole range of burst dropping probability.

3. PROBLEM FORMULATION

Transmission Control Protocol (TCP) is a transport-layer protocol designed to provide a reliable end-to-end delivery of data over unreliable networks, and it performs well over conventional wired networks. However, TCP encounters some challenges in multi-hop ad hoc networks. Due to the instability and shared wireless channels, ad hoc networks may suffer from impairments, e.g., route failures due to dynamic topology, packet drops due to Medium Access Control (MAC) contentions and interference, and random channel bit errors. Performance of TCP significantly degrades in ad hoc networks because TCP connections in such networks are influenced by various factors such as high bit error rates, frequent route changes, and partitions. If we run transmission control protocol (TCP) over such connections, then throughput of the connection is observed to be extremely poor because TCP treats lost or delayed acknowledgments as congestion.

4. CONCLUSION

In this paper, we present a brief survey on the issues faced by TCP in mobile ad hoc network and recent efforts to improve its performance. Due to some inherent characteristics of ad hoc network like time-varying wireless channel, medium collision, and mobility, traditional TCP suffers from performance degradation which performs well in fixed wired networks. Here we present some enhancements of TCP protocol to increase the TCP performance over ad hoc network. But none of these solutions countermeasures all the issues related to TCP over ad hoc network. In the future, we intend to find out such a solution which will perform well for every issue related to TCP over mobile ad hoc network.

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