ISSN(Online): 2320-9801
ISSN (Print) : 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 5, May 2016

Evaluating Relevance of Loss-Tolerant TCP as Means of Improving the Performance of TCP over MANETs

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ABSTRACT: The TCP / IP protocol is key to flow of information as it manages the flow of information between computers and network programs. This protocol allows the data sent to be delivered to its destination without error and under the same structure in which sender sent them. TCP was originally designed to work in the wired environment, but given the widespread usage, it was eventually adopted across wireless networks as well. But a key differentiator affecting the performance of TCP in wireless networks, and more so in Mobile Ad-Hoc Networks, is the inability of TCP to differentiate between congestion and losses. Loss Tolerant TCP was proposed as a solution to address this very issue and make TCP robust for the wireless networks. Hence, the main aim of this paper is to revalidate the significance of gains, if any, that LT-TCP may provide over traditional TCP.

KEYWORDS: MANETs, LT-TCP, MANET Performance, Losses in MANETs

I. INTRODUCTION

The TCP / IP protocol is very important it manages the flow of information between computers and network programs. This protocol allows the data sent to be delivered to its destination without error and under the same structure in which sender sent them. TCP was originally designed to work in the wired environment, but given the widespread usage, it was eventually adopted across wireless networks as well. But a key differentiator affecting the performance of TCP in wireless networks, and more so in Mobile Ad-Hoc Networks (or MANETs (1)), is the inability of TCP to differentiate between congestion and losses. Loss Tolerant TCP (2)(3)(4)was proposed as a solution to address this very issue and make TCP robust for the wireless networks. Hence, the main aim of this paper is to revalidate the significance of gains, if any, that LT-TCP may provide over traditional TCP.

II. LITERATURE REVIEW AND RELATED WORK

With the spread of the Internet and Network globally, TCP/IP, primarily owing to its reliability, has been adopted as protocol of consensus thus forcing its standardization. Thus, the TCP / IP packets are the driving of all Internet traffic. These packets attach content to the information sent and received via the network whether text, images or a simple email. Many other points deserve comment about TCP / IP, because it is, in short, the essential tool of computer network communication, but more important to know is to qualify it in the tools or solutions that are part of the core of a system. All the issues and aspects related to the deployment of LT-TCP for improving performance of TCP over Mobile AD-HOC networks will be discussed in detail in this paper.

A. *Desired Behavior of TCP:*

Computer networks provide a rapid transit mechanism for many kinds of information, but while these networks are fast, they are not necessarily reliable. Inherent to the computer networks are those problems that impede reliable transfer of information, some of whichinclude the potential reordering of data packets sent over the network, the possibility that a packet may be lost in transit, and the congestion on the heavily trafficked nodes within the network. To combat these issues and provide a reliable network communication platform to application developers, the

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Transmission Control Protocol was created with facilities to assure complete and in-order delivery of network transmissions while detecting and controlling congestion within the network.

To provide this reliable network platform, TCP makes some assumptions about the behaviour of the underlying network links. In particular, TCP assumes that a lost packet is in most likelihood an indicator of the network congestion, and therefore uses packet losses as a symbol of network congestion and hence, the transmitterof data should, accordingly, reduce the send rate to alleviate the congestion

B. *Introduction to LT-TCP and its Comparison with Standard TCP:*

In the first case, in regards to the main mechanism of TCP Protocol, the LT-TCP was compared with other protocols as well in the topic. Actually, Loss-Tolerant TCP (LT-TCP) was created to address these weaknesses of TCP on wireless networks. By utilizing Explicit Congestion Notification (ECN), LT-TCP eliminates the assumption that losses are a reliable indicator of congestion and processes these events separately, enabling it to fully utilize networks where physical losses are present without neglecting congestion control. Furthermore, LTTCP estimates the network loss rate and utilizes Forward Error Correction (FEC) packet encoding to proactively repair losses and avoid retransmissions. If the Proactive FEC (PFEC) is not sufficient for the receiver to completely recover the transmitted data, Reactive FEC (RFEC) is sent, which is analogous to TCP retransmission. By using a combination of proactive and reactive FEC, LT-TCP is able to correct for losses and avoid retransmissions(5).

LT-TCP is designed as a drop-in replacement of TCP, to be implemented in the kernel using the same API that TCP uses thus requiring minimal changes (if any) to applications in order to use LT-TCP instead of TCP. A kernel implementation also enables LT-TCP to accurately record timing statistics from the network and facilitates efficient implementations of the coding algorithms, which can run in the kernel with minimal overhead. LT-TCP does require ECN to be deployed on networks before it can be used on them. Although ECN is defined in an RFC and supported by most major operating systems, its deployment has been somewhat slowed by network appliances such as firewalls and routers which process it incorrectly and either clear the ECN flags in packets, or drop the packets entirely; nevertheless, ECN adoption is increasing(6).

III. Increased Significance of MANETs in Modern World

A mobile ad hoc network (MANET) is a self-configuring communication system that uses the nodes themselves as not only sources and sinks but also routers(7). Nodes in a MANET are typically battery-operated devices with the limited-range, half-duplex radios for communication. MANETs are easy to set up and use since their operation does not depend on any fixed infrastructure(8). There are many applications that can benefit from MANETs(7) such as

A. *Military tactical operations:*

A communication network that relies on a certain infrastructure is not desirable for military tactical operations, as it constitutes a soft spot in hostile environments. Elimination of the need for the hard/impossible to set up fixed infrastructure makes MANETs perfect candidates for such operations.

B. *Search and rescue missions:*

From time to time, search and rescue missions need to be performed in the remotest of the locations with no basic communication infrastructure or a base station to hook-up to, including locations such as the top of a mountain, the middle of a forest or inside a cave. MANETs are easy to use communication systems for such scenarios.

C. *Disaster relief:*

MANETs provide communication in environments where existing infrastructure is destroyed or left inoperable.

D. *Law enforcement*

Law enforcement operations can be extended to include locations with no communication infrastructure. MANET systems provide fast and secure communication in such scenarios.

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E. *Commercial use*

MANETs can be used to support data exchange between people and applications in large meetings and conventions.

MANETs are unique among communication networks, as can be observed from the vital application areas. However, the unique characteristics required by these applications necessitate unique solutions and differentiate MANETs from other conventional networks. There are various challenges that have to be taken into account when designing a MANET. First of all, the communication channel between the nodes in the network is highly unreliable. A MANET operates over wireless channels that incur higher bit errors compared to wired interfaces. MANET protocols have to be designed with the assumption of an erroneous channel. MANETs also are designed to work in any environment, whether it is a desert, forest or mountainous region(9).

The lack of prior knowledge about the propagation characteristics of the wireless medium also presents challenges to protocol design for MANETs. Node mobility is another challenge in the design of MANETs. The topology of a MANET can change not only with changing propagation characteristics of the medium but also due to the mobility of the nodes in the network. In order to reliably convey information, MANET protocols have to include mechanisms for proper mobility management. Having limited storage and computational capabilities further restrict the range of algorithms that can be used in MANETs. Moreover, MANETs have limited bandwidth and energy resources(10).

IV. EXPERIMENTAL SETUP

The Experimental Network Configuration is basically a reference to the experiments conducted by other authors in the past. The main reason to conduct an Experimental Network Configuration was to highlight vital elements associated with various kinds of protocols that have been practically tested as well at different situations. All the details are mentioned in the following paragraphs:

A. *Brief Description of Test-Bed*

The network used for testing consists of three computers on a 1Gbps Ethernet LAN. There are two endpoint machines that send and receive data, and one machine used as a bridge between the endpoints that applies network conditions according to a specified configuration. All three machines are also connected to an independent control LAN, which is used to send control messages between the machines to schedule experiments and report their results.

B. *Observations*

The TCP and LT-TCP protocols perform handshakes both to establish a connection before transmitting data and to terminate a connection after all data has been delivered to the application layer. To prevent packet losses during these handshakes from creating unnecessary noise in the experimental results, the connection and disconnection handshakes are performed without any losses applied to the network and are excluded from timing results(11).

An experiment with losses and high latency proceeds as follows:

Step 1: Experimentalconfiguration is sent to bridge
Step 2: Bridge applies high latency
Step 3: Endpoints perform connection handshake
Step 4: Bridge applies packet losses
Step 5: Endpoints perform data transfer
Step 6: Bridge disables packet losses
Step 7: Endpoints perform disconnection handshake
Step 8: Bridge disables high latency
Step 9: Timing results are collected only during step 5 above.

C. *Findings*

These results are collected at the application layer on the system receiving the data. The time result for the transfer is measured from the time the first byte is received to the time the entire transfer has been received. The number of steps involved in each experimental transfer necessitated the construction of an automated test harness. The harness is composed of three separate programs: a graphical interface which runs on the operator's computer, a network controller daemon which runs on the bridge, and an endpoint daemon which runs on each endpoint system (10).

The majority of logic here is in the network controller daemon. It is responsible for applying the network conditions (packet loss profile, link delay, ECN marking) using Network Emulator a feature of the Linux kernel which allows the application of various network conditions on packets passing through the system; configuring endpoint daemons; coordinating transfers; and relaying the status and results of experiments back to the user interface. For greatest accuracy, the final timing results for individual transfers are generated at the endpoint receiving the data transfer, and then sent to the controller daemon over the control LAN for statistical analysis(11).

D. *Identified Limitations in Test-Bed possibly impacting the outcome*

When a round of tests is complete, the results are returned to the user interface. The user interface to the test harness does not do any processing directly; it simply informs the network controller as to what kind of experiment is desired and reports the statistics received from the controller to the user. The test harness supports performing transfers over various network profiles based on tuneable packet loss, ECN marking, and/or delay options. Packets moving over the test network in either direction between endpoints can be delayed by a specified time period by applying the symmetric delays specified manner. The delay profile can be applied alongside either packet loss or ECN marking, but due to limitations in Network Emulator, a single bridge system cannot affect both packet losses and ECN marking on the network simultaneously.

E. *Recommendations in consideration of Limitations*

A loss profile can be applied and set to either the dropped packets or mark them with ECN, but not both. The operator can specify a loss or ECN profile and a latency or link-delay to the test harness, and the harness will automatically perform a series of tests and yield the average and standard deviation of the transfer times (10).

V. Conclusion and Future Work

There are some outstanding issues in the LT-TCP reference implementation used to collect these results that should be understood.

First, the implementation currently has some faults in its RTT estimation algorithm that causes it to overestimate the round trip time of the network and sometimes calculate extremely large values. This causes LT-TCP to select the maximum timeout (this is 120 seconds in Linux) before continuing transmission although no acknowledgments have returned. This is normally not an issue, but under correlated packet losses it is common for an entire send-window of the packets to be dropped, forcing the sender to wait for the timeout before sending any more data, which may be dropped as well, delaying for another timeout. This problem is particularly prevalent early in the slow-start phase when the send-window is only a few packets in size.

The second outstanding issue here is that LT-TCP's packets in flight counter is overly simplified, and should be developed further. If the packets in flight are greater than or equal to the size of the congestion window, no new packets are sent until some packets leave the network. This is how congestion control is enforced. At present, the LT-TCP packets in flight counter is reset to zero if no acknowledgments are received, the congestion window is full, and the retransmission timeout expires with outstanding packets waiting to be sent. It is assumed that if the timeout expires with a full congestion window, an entire send-window has been lost, which is fairly common with correlated losses, especially early in the connection when the congestion window is small. This solution ensures completion of transfers, but introduces other issues.

Even so, there are some outstanding issues in LT-TCP that must be addressed. As in previous work, LT-TCP performance is lower than TCP's when no losses are present. While this is not particularly surprising, since Linux's TCP implementation is the product of decades of refinement by professional developers well familiarized with low level software optimization, it does somewhat diminish LT-TCP's attractiveness for implementation in real-world applications, so further optimization of LT-TCP is necessary. Furthermore, there continue to be defects in the reference implementation, and some protocol revisions proposed in this thesis have yet to be tested.

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ISSN (Print) : 2320-9798

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Vol. 4, Issue 5, May 2016

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