Analysis & Development of Dynamic TLPs in the use of Smart Mobile Device Communication

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Degree of Bachelor of Science

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Sri Lanka

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Group ID: 15-019

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Dissertation submitted in partial fulfillment of the requirements for the degree of Science

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Declaration

We hereby declare that the project work entitled "Analysis & Development of Dynamic TLPs in the use of Smart Mobile Device Communication", submitted to the Sri Lanka Institute of Information Technology is a record of an original work done by us, under the guidance of our Supervisor Mr. Dhammika H. De Silva. This project work is submitted in the partial fulfillment of the requirement for the award of the degree of Bachelor of Science (Special Honours) in Information Technology. The results embodied in this report have not been submitted to any other University or Institution for the award of any degree or diploma. Information derived from the published or unpublished work of others has been acknowledged in the text and a list of references is given.

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Abstract

Smart Mobile devices has revolutionized the human behavior with the introduction of different apps that helps it users in day today activities. We often see Smart devices are in use to help with not just ordinary activities but also for users with special needs. Data transferring in real time path navigation systems with obstacles has to be high speed, efficient and reliable. This requires information with minimal time to reach its destination to avoid hazardous encounters discover the required path, identify real time changes on the path in the current map and give out alternative routes. Our research will look into models and methods to facilitate the bounded timing of which it takes the minimum time for path finding application for people with vision disabilities.

Given a comprehensive analysis of the requirements that are put forward in path navigation applications, it was identified the existing transport layer protocols are not the best option and is ideal for the requirements that we are looking into. I.e. transporting the data with urgent flags, congestion control in the use of Smart Mobile communication. Our research investigates existing TLPs and proposes extensions and modifications to facilitate the required short comings in the use of Smart Mobile communication and will implement Dynamic TLP to incorporate.

Acknowledgement

We would like to express or deepest gratitude to those who helped in with various inputs, suggestions and wisdom when completing this task of Analysis & Development of Dynamic TLPs in the use of Smart Mobile Device Communication.

Our first and foremost thank you goes to our Supervisor, Mr. Dhammika H De Silva for being our guiding start providing us with all the literature and help needed when understanding the concept of a Research Project and its application for better prospects in our lives in the aspect of learning through research. If it’s not for him we would not be able to perform the tasks oriented through this research and complete it with fullest confidence in our capacity as undergraduates. He has been always available for us with directions and action points to proceed through the correct path of navigation.

We would also like to thank our lecturer in charge of the module CDAP for keep us focused on the outcomes of a research and encouraging us to pursue the light of a patch to become a confident graduate.

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1. Introduction

Modern world revolves around networks which have access to details, information any corner in world and can be accessible fast. We often use this information to ease our day to day activities be updated with new things, be connected to people around the world and many more.

We have evolved from using information for the purpose of simple/advance activities to real time quick updates for the purpose of medical reasons, navigation, bank transactions, aviation industry etc.

We find it's very important to focus on transport layer protocols which possess reliable, high speed and efficient data transfer methods which are vital factors in real time path navigation systems which require information within a short time duration to discover paths, avoid hazardous encounters providing alternatives. There's always a demand for reliable information that is accessible in quick successions without having to wait for long. A second delay can cause a lot of damage in a real time system. We identify the current protocols that are being used in TLP has certain faults/ draw backs that prevents the quick succession of transfer of data or retransmit to serve information to its uses.

1.1.1 Background information and overview of previous literature survey

In computer networking, the transport layer or layer 4 provides end to end communication services for applications within a layered architecture of network components and protocols. The transport layer provides convenient services such as connection oriented data stream support reliability, flow control and multiplexing. A comparison of prominent transport layer protocols used in this research is shown below. [1]

	TCP	UDP	DCCP	SCTP
Connection Oriented	Yes	No	No	No
Reliable	Yes	No	No	Yes
Congestion Control	Yes	No	Yes	Yes
Ordered/Unordered delivery	Ordered	Unordered	Unordered	Both
Retransmission flow	End to End	End to End	End to End	End to End

Table 1.Comparison of transport layer protocols

The project team conducted a thorough literature survey focusing on research papers such as “Impact of Mobile Wireless Links on TCP Performance” by Haowei Bai *et al* [2] which states that TCP will still be the dominant end-to-end reliable transmission control protocol at least in the near future; However, TCP was initially designed to perform well in networks with reliable wired links and stationary hosts, where packet losses are mainly due to network congestion. TCP assumes that all packet losses are due to network congestion.

“Internet Accessibility In High-Speed Vehicles” by Hala Eidaw *et al* [3] was another paper analysed which mentioned that computer and wireless communication require internet accessibility at anytime and anywhere, this includes in a high-speed mobile station such as in speedy trains, fast moving cars as vehicle-to-infrastructure communication. This increased the development of numerous schemes concerning the need of smooth handover of the mobile nodes.

Moreover focusing on the issues in these protocols, Ibtissam El Khayat *et a*l [4] states in his research “Improving TCP in wireless networks with an adaptive machine-learnt classifier of packet loss causes” that nowadays, many applications use TCP as their transport protocol and hence pass through wireless links, which become common in the Internet. Over these links, packet losses are not due anymore only to overthrows but can also be caused by link errors. TCP, which has no mechanism to distinguish packet loss causes, reduces its rate at each packet loss. As a solution the researchers propose to apply a particular learning algorithm called decision tree boosting to automatically design a model for discriminating the two possible packet loss causes and then use this model at best to improve the performance of TCP in wired/wireless networks.

In “Transport Layer Fairness and Congestion Control in Multihop Wireless Networks” it states that experiments and research showed that TCP's congestion control algorithm performs very poorly over wireless ad hoc networks with degraded throughputs and severe unfairness among flows. This paper studies TCP's fairness and throughput issues in wireless ad hoc access networks, and designs an improved congestion control algorithm based on the characteristics of the wireless ad hoc access networks. The protocol is designed as extension to DCCP (datagram congestion control protocol) with a new congestion control component. The research was done by Kunz.T et al [5].

“Improving TCP Startup Performance using Active Measurements:Algorithm and Evaluation” by Ningning Hu *et al* [6] is another such study analysed which mentions that TCP slow start exponentially increases the congestion window size to detect the proper congestion window for a network path. This often results in significant packet loss,while breaking off Slow Start using a limited slow start threshold may lead to an overly conservative congestion window size. This problem is especially severe in high speed networks. In this paper we present a new TCP startup algorithm, called Paced Start that incorporates an available bandwidth probing technique into the TCP startup algorithm.

TCP implementation in Linux

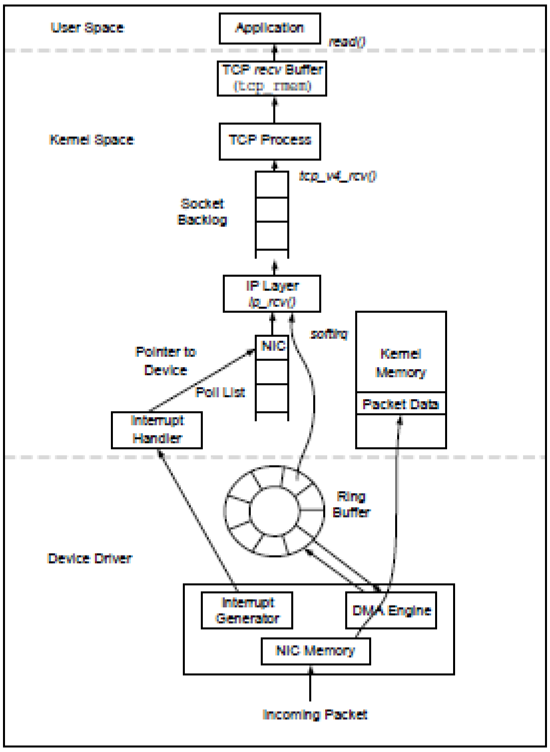


Figure 1.1 Packet Reception 1

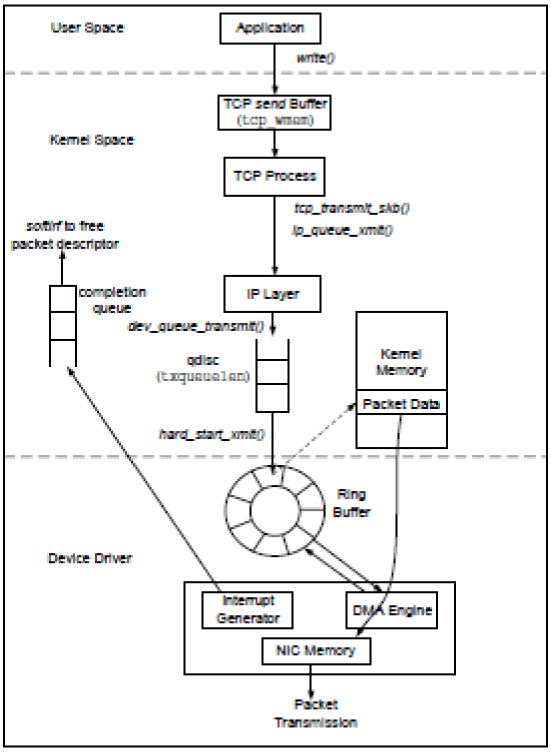


Figure 1.2 Packet Transmission 2

Figures 1 and 2 show the internals of the TCP implementationin Linux kernel. Fig. 1 shows the path taken by a new packet from the the wire to a user application. The Linux kernel uses an *sk buff* data structure to describe each packet.When a packet arrives at the NIC, it invokes the DMA engine to place the packet into the kernel memory via empty *sk buffs* stored in a ring buffer called *rx ring*. An incoming packet is dropped if the ring buffer is full. When a packet is processed at higher layers, packet data remains in the same kernel memory, avoiding any extra memory copies. Once a packet is successfully received, the NIC raises an interrupt to the CPU, which processes each incoming packet and passes it to the IP layer. The IP layer performs its processing on each packet, and passes it up to the TCP layer if it is a TCP packet. The TCP process is then scheduled to handle received packets. Each packet in TCP goes through a series of complex processing steps. The TCP state machine is updated, and finally the packet is stored inside the TCP *recv* buffer.

1.1.2 Behavior of Data Transfers

In the research "An investigation in to Dynamic TLP's for Smartphone Communication" It is said, The way finding application designed for Vision Impaired People requires efficient data transfer in between Building Information Model (BIM) and the person with disability - Infrastructure Network and among the peers (Ad-hoc network). This research identified the size of data, data transfer frequency, reliability, transfer direction and type of the network. Table I shows the summery of identified data transfers and behaviour of data in this system [1]

The mobile device of the vision impaired person will capture the GPS, Wi-Fi and sensor data depending on availability and processed data will be send client to server. This data has very small payload. Due to the very high data transfer frequency the end-to-end reliability is not required. If one segment lost, there is another within very short bounded time. [1]

In the case of a change in the existing map (Obstacle-Fixed), mobile device will be triggered to transfer data to the server. [1]

Data	Size	Transmission Frequency	Delivery Reliability	Direction	Network
GPS - Processed	Very Small	High	No	C → S	I
Wi-Fi - Processed	Very Small	High	No	C → S	I
Obstacle - Fixed	Medium	Triggered	Yes	C → S	I
Obstacle – non stationary	Small	Urgent	Yes	C → S C → C	A, I
Map Data	Large	Triggered	Yes	S → C, C → S	I
User Location	Very Small	High	No	C → S C → C	A, I
Sensor data -Processed	Very Small	High	No	C → S	A, I
Instruction	Small	Urgent	Yes	S → C C → C	A, I

Table 2.Comparison of different data types over network

C- Client, S-Server, A – Ad-hoc, I-Infrastructure

As a summary of the literature review conducted formerly, it was understood that these transport layer protocols were originally developed for wired networks. However due to many reasons such as security, stability, convenience and unlimited roaming and range the protocols were used in wireless networks as well. Yet many shortcomings began to occur and as alternatives, modified versions of these same protocols were developed such as TCP-Reno, UDP-lite.

1.1.3 Identification and significance of the problem

- **Packet losses during transmission**

TCP has been deployed in the 1980s. Its congestion control is based on the fact that packet losses are mainly due to buffer overthrows and it works quite well in such situations. However, nowadays, many applications use TCP as their transport protocol and hence pass through wireless links, which become common in the Internet. Over these links, packet losses are not due anymore only to overthrows but can also be caused by link errors. TCP, which has no mechanism to distinguish packet loss causes, reduces its rate at each packet loss. This reduction is not justified when there is no congestion and the consequence is that the throughput of TCP over wireless link is lower than what it could be. Research conducted by Ibtissam El Khayat [7].

- **Congestion control in data transmission**

TCP (Transmission control protocol) is a reliable, end-to-end transport protocol, which is widely used for data services and is very efficient for wired networks. However, experiments and research showed that TCP's congestion control algorithm performs very poorly over wireless ad hoc networks with degraded throughputs and severe unfairness among flows by Dr. Thomas Kunz [8].

In fact, the simplest way to solve congestion is to employ the principle of packet conversation in which the sender stops sending a new packet until the previous one is successfully delivered to the receiver. For this reason, the TCP protocol, one of the core protocols of the Internet protocol suite, employs the concept of congestion control which dynamically controls the flow of packet inside a network, and prevents network performance collapse. Research conducted by van Jacobson [9].

- **Error control**

This paper we propose a new scheme that can efficiently deliver multimedia over wireless Internet. Packet losses due to congestion or random error can be distinguished in our scheme. Proper congestion control and error control are performed, which are suited for multimedia applications. Featured with retransmission mechanism, our scheme can also reduce the packet loss ratio caused by fading and random errors, conducted by Fan Yang [10].

- **Improve wireless TCP performance**

This paper, they describe the design and implementation of a simple protocol to alleviate this degradation and present the results of several experiments using this protocol. Their aim is to improve the end-to-end performance on networks with wireless links without changing existing TCP implementations at hosts in the fixed network and without recompiling or relinking existing applications. They achieve this by a simple set of modifications to the network-layer (IP) software at the base station. These modifications consist mainly of caching packets and performing local retransmissions across the wireless link by monitoring the acknowledgments to TCP packets generated by the receiver. Their experiments show speedups of up to 20 times over regular TCP in the presence of bit errors on the wireless link. They have also found that their protocol is significantly more robust at dealing with multiple packet losses in a single window as compared to regular TCP. Conducted by Hari Balakrishnan [11].

This paper makes two important contributions. First, they design a network-based solution called the Window Regulator that maximizes TCP performance for any given buffer size at the congested router. Second, they present a scheduling and buffer sharing algorithm that reduces the latency for short flows while exploiting user diversity, thus allowing the wireless channel to be utilized efficiently [12].

This research, explore a new way to make TCP adapt to frequent route changes without relying on feedback from the network. It is based on TCP detecting out-of-order delivery events and inferring route changes from these events. They call it Detection of Out-of-Order and Response (DOOR). Their study has shown that this approach can significantly improve TCP performance over mobile ad-hoc networks [13].

- **Flow Control**

The performance of TCP degrades over wireless links due to high rate of data losses, which are falsely perceived as network congestion state. TCP performance metrics also diminish due to low data rate, since large delays may occur in last link i.e. wireless link. Similarly in heterogeneous wireless network, packet loss may also occur due to mobility-events that can cause burst-losses, service-disconnection. This motivates to reevaluate TCP control operations and embed some mobility related services to optimize its performance for new generation of wireless networks. TCP for mobile, wireless environment with the help of link-layer triggers which shall be standardized by IEEE 802.21 standard, through its media independent handover (MIH) services. These services are used to detect link layer events in the TCP control operations, and act accordingly to adjust flow and congestion control in a way that does not seriously hamper TCP performance by Muhammad Saeed Akbar. [14]

- **Performance Enhancement of TCP**

Nodes in are distributed and can be statics or mobile. The main advantage of Ad-hoc Networks is that its nodes can be self-organize allowing nodes to connect to each other. The connections between the nodes do not need to establish preexisting infrastructure like other networks. Each node can work as a router to route data to its neighbor nodes. Ad – hoc networks can be used in places that can be difficult to prepare it with infrastructures like open areas. [15]

- **Improving Transport Layer Performance in Multihop Ad Hoc Networks**

TCP congestion control has an implicit assumption, i.e., any packet loss is due to network congestion. However, this assumption is no longer valid in the ad hoc networks as packet losses may well be due to channel errors, medium contention, and route failures.

Several works have pointed out that greedy TCP can result in severe congestion in ad hoc networks and hence performance degradation. Subsequently the TCP source will reduce congestion window size before it becomes excessively large. To avoid congestion, Chen et al. dynamically adjusted the congestion window limit according to path length of TCP flows, a neighborhood RED scheme was proposed to alleviate TCP fairness problem by adjusting marking/dropping probability in light of observed channel information. [16]

In terms of how novel the research topic is it could be considered different and unique since currently such protocols designed for wireless networks within the transport layer are rarely used.

One such protocol is the Wireless Application Protocol (WAP) which is a technical standard for accessing information over a mobile wireless network. A WAP browser is a web browser for mobile devices such as mobile phones that uses the protocol.

The WAP standard described a protocol suite allowing the interoperability of WAP equipment, and software with different network technologies, such as GSM and IS-95(also known as CDMA). [8]

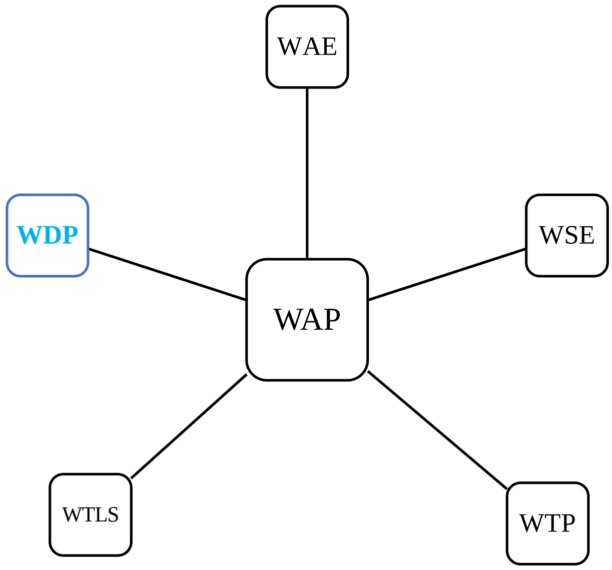


Figure 2. WAP protocol Suite

However the only transport layer protocol within this suite is WDP (WAP Datagram Protocol).

Wireless Datagram Protocol defines the movement of information from receiver to the sender and resembles the User Datagram Protocol in the Internet protocol suite. It is a protocol in WAP architecture, covers the Transport Layer Protocols in the Internet model. By letting only the transport layer deal with physical network-dependent issues, global interoperability can be acquired using mediating gateways.

Disadvantages of the WAP architecture:

- Thin client architecture
- Normal web technology cannot be used in WAP client
- WAP clients are limited to handheld wireless devices such as mobile phones
- Slow speed of access
- Limited availability

In the research done by Sankara Krishnaswamy on “Wireless Communication Methodologies & Wireless Application Protocol” it is termed that during the study 70% of the users rejected the idea of WAP enabled phones. Some of the disadvantages of WAP clearly made the users to decide not to like this. Because of the misguided use of design principles from traditional Web design, the usability of the **current WAP services is reduced considerably**. WAP is facing the same problem as WEB designs faced in 1994 during the evolution of the Internet. For example, some of the WAP designs that use more screens to display information could have been displayed in a lesser number of screens. This kind of design may work on the Web if users have a big-screen PC, but on a small-screen device, designers must cut short each service down to its essence and show much less information. The time taken to perform a query on the Internet through the WAP is also not acceptable by the users.

Thereby it is vital that an accurate wireless protocol suited for the transport layer is designed. It should be able to avoid the existing drawbacks of the above mentioned wired and wireless protocols. This would be the height of significance this research project is aimed at.

1.2 Research Gap

These existing Transport Layer Protocols (TLP's); mainly TCP since it has a high rate of data packet loss and high retransmission time when operating in wireless networks.

There are various additions and enhancements of both TCP and UDP, such as Multipath TCP[15], Datacenter TCP[16] or UDP-Lite. These protocols are often designed for a specific use case or mitigate a common drawback of the original transport protocol. TCP does more than just break things up into packets. It also makes sure that the data arrives, resending packets where necessary. But for a question that fits in a single packet, we don't need all the complexity of TCP to do this. There's always a demand for reliable information that is accessible in quick successions without having to wait for long. A second delay can cause a lot of damage in a real time.

All new TCP-like protocols are only modification of basic TCP - Protocols. In them there are no essential changes. The behavior of these new Protocols is more or less good, but all of them have not only advantages but also lacks. Process of replacement is very slow and should be very long.

We identify the current protocols that are being used in TLP has certain faults/ draw backs that prevents the quick succession of transfer of data or retransmit to serve information to its uses. There's always a demand for reliable information that is accessible in quick successions without having to wait for long. A second delay can cause a lot of damage in a real time system.

In our proposed system we focus to develop a protocol that support minimal packet drops and takes a low retransmission to transmit data in quick successions with in a wireless environment. This has been identified as a very important factor in real time systems which are focusing on path navigation applications and other related areas which gather information on critical information like patients, avoid accidents for disabled while providing alternate routes in navigation systems in instances of impediments.

1.3 Research Objectives

1.3.1 Main Objective

To design an enhanced dynamic transport layer protocol which adapts itself according to the data that's being transmitted across a network. For an example if there's any urgent data that needs to be transmitted immediately, a different approach will be used rather than using the conventional transport layer protocol, TCP, which is proven to be inefficient in such situations.

1.3.2 Sub Objectives

- Analysis & classification of application layer data in order to determine which method/functionality to be used in transmitting those data.

- Examining the currently available transport layer protocols & analyzing their behavior to identify their drawbacks.

- Handover method analysis to significantly improve the connection establishment process & to reduce the no of times a particular client has to establish a connection.

- Analyzing the modifications that can be applied to the currently available protocols.

2 Methodology

2.1 Execution of Methods in TCP to suite the Dynamic TLP

We have found different methods ie. Congestion control, Floor control, Error control as properties of TCP that's developed to transfer large amount of data with its diagnosed properties. We wanted to identify a way where we can change the order of these method executions happening in the TCP in order to facilitate the requirements of the DTL protocol in a situation where urgent data transfer is needed.

2.1.1 Congestion Control

TCP flows start with an initial congestion window of at most three segments or about 4KB of data. Because most Web transactions are short-lived, the initial congestion window is a critical TCP parameter in determining how quickly flows can finish. While the global network access speeds increased dramatically on average in the past decade, the standard value of TCP's initial congestion window has remained unchanged.[17]

A proposal has come forth to increase TCP's initial congestion window to reduce Web latency during the slow start phase of a connection. TCP uses the slow start algorithm early in the connection lifetime to grow the amount of data that may be outstanding at a given time. Slow start increases the congestion window by the number of data segments acknowledged for each received acknowledgment. Thus the congestion window grows exponentially and increases in size until packet loss occurs, typically because of router buffer overflow, at which point the maximum capacity of the connection has been probed and the connection exits slow start to enter the congestion avoidance phase. The initial congestion window is at most four segments, but more typically is three segments 0Paper is under review for publication. for standard Ethernet MTUs (approximately 4KB)[18]. The majority of connections on the Web are short-lived and finish before exiting the slow start phase, making TCP's initial congestion window (init cwnd) a crucial parameter in determining flow completion time. Our premise is that the initial congestion window should be increased to speed up short Web transactions while maintaining robustness.

Congestion control is one of the performance metrics of TCP protocol. There are so many TCP Versions to control congestion in the network.
NS2 also supports various TCP protocols like TCP Vegas, TCP Reno, TCP, TCP Sack, Full TCP, TCP linux, etc.

Each TCP protocols has different mechanism in controlling the congestion. Some are good at Congestion control, some are good at error and flow control.

2.1.1.1 Steps that were needed to carry out the operation.

- Investigating the congestion control in TCP
- How NS2 handles congestion window size
- Output can be shown through a plotted graph

Before understanding the congestion control, one has to know the congestion window of TCP. TCP has a congestion window (cwnd_ in ns2), this variable affects or predicts the congestion control.

The value assigned to this variable will alter the congestion control. Here are the files that are of prime importance before dealing with congestion control.
~ns-2.35/tcp/tcp.cc
~ns-2.35/tcp/tcp.h
~ns-2.35/tcl/lib/ns-default.tcl (In this file, the constant values for all the protocols in ns2 are set)

For example, the packet size of CBR is 210 by default, this value is represented like this in the ns-default.tcl file.

```
Application/Traffic/CBR set packetSize_ 210
```

if you want to change the packet size of CBR for ns2, you may change the above line to

```
Application/Traffic/CBR set packetSize_ 500
```

which is set to 500 bytes, the above line will affect the entire tcl scripts (the value is changed to 500), instead the packet size can be changed within the TCL file where it is programmed as given below

```
set cbr [new Application/Traffic/CBR]
$cbr set packetSize_ 500
```

The above line will change the packet size for this file only. Similarly, the TCP congestion window is set like this

```
Agent/TCP set cwnd_ 0
```

the default value is 0 and you may modify this within the file as given below

```
set tcp [new Agent/TCP]
$tcp set cwnd_ 3
```

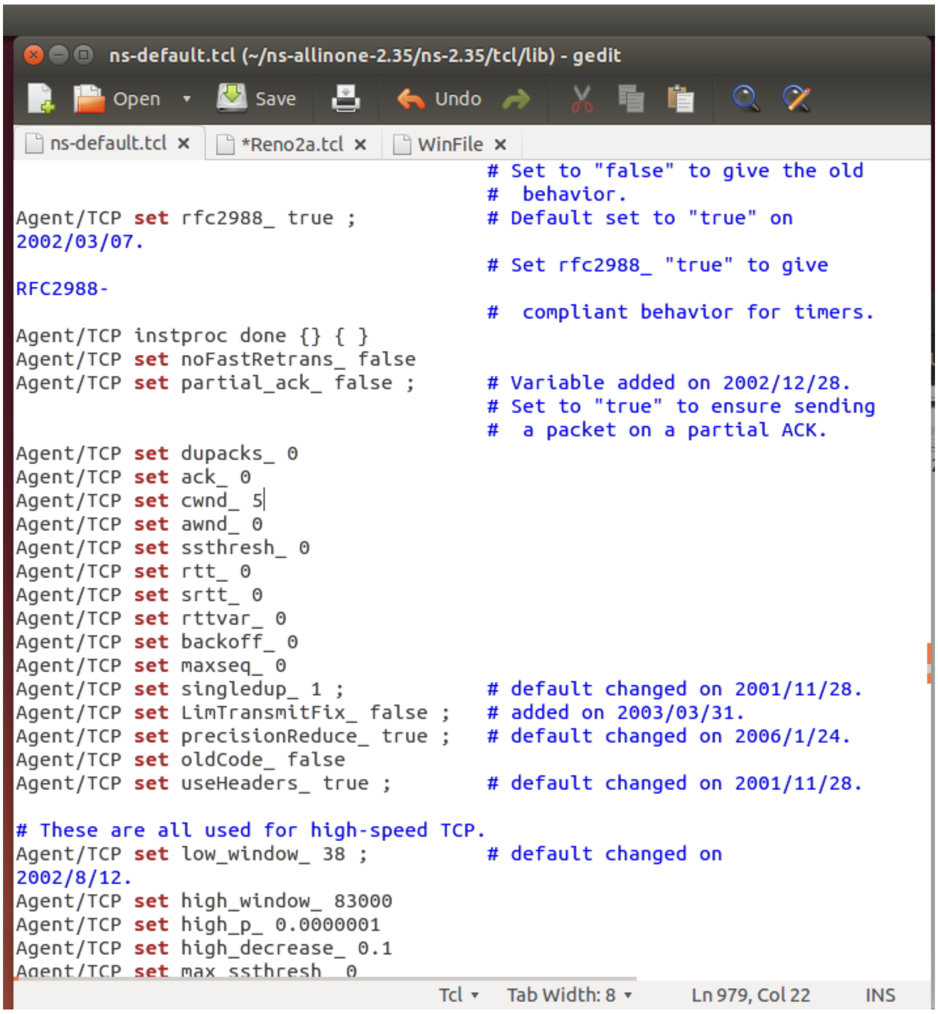
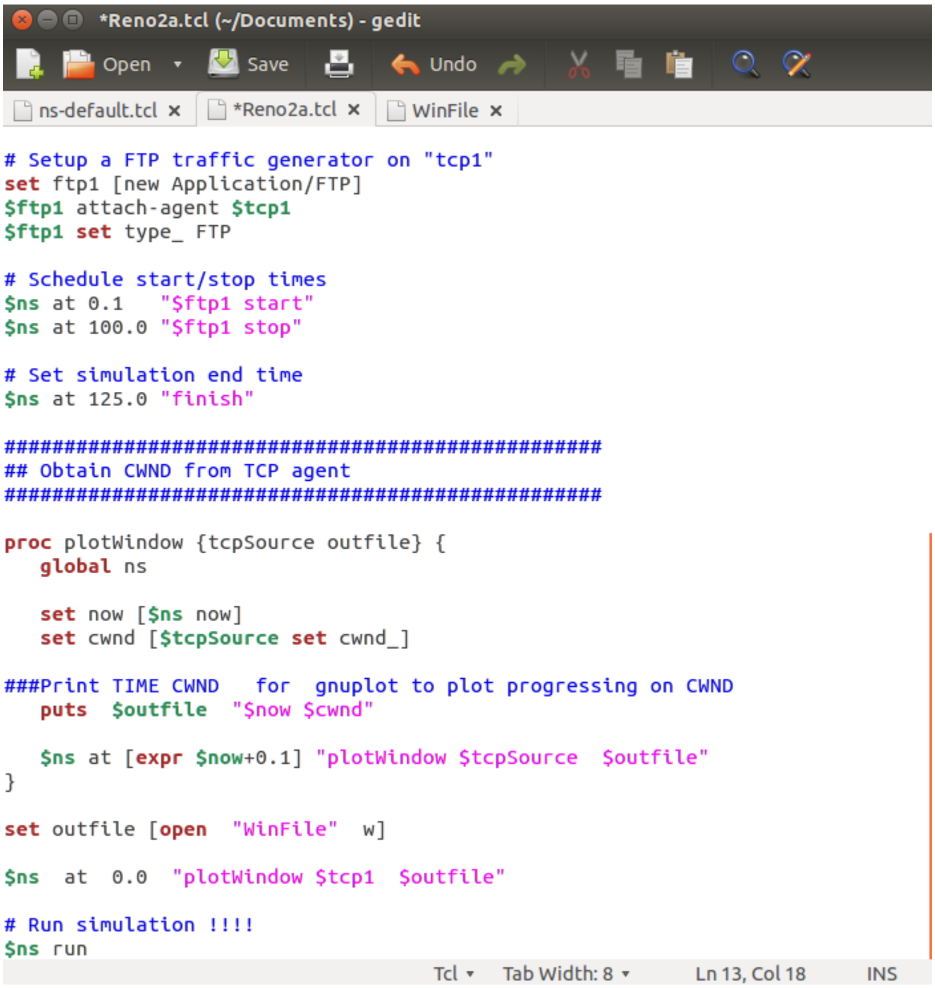


Figure 3.Amended Congestion window from 0 to 5.

- In ns-default.tcl, by default cwnd_ is set to 0.
- It is now changed to 5.




```
# Setup a FTP traffic generator on "tcp1"
set ftp1 [new Application/FTP]
$ftp1 attach-agent $tcp1
$ftp1 set type_ FTP

# Schedule start/stop times
$ns at 0.1   "$ftp1 start"
$ns at 100.0 "$ftp1 stop"

# Set simulation end time
$ns at 125.0 "finish"

##################################################
## Obtain CWND from TCP agent
##################################################

proc plotWindow {tcpSource outfile} {
   global ns

   set now [$ns now]
   set cwnd [$tcpSource set cwnd_]

###Print TIME CWND   for  gnuplot to plot progressing on CWND
   puts  $outfile  "$now $cwnd"

   $ns at [expr $now+0.1] "plotWindow $tcpSource  $outfile"
}

set outfile [open  "WinFile"  w]

$ns  at  0.0  "plotWindow $tcp1  $outfile"

# Run simulation !!!!
$ns run
```

Figure 4. A procudure to develop the plot graph

Introducing the new procedure to print the congestion window on its expansion for each second.

Output of which confirm that the congestion window is increased to accommodate the argument that faster transmissions could be expected via TCP.

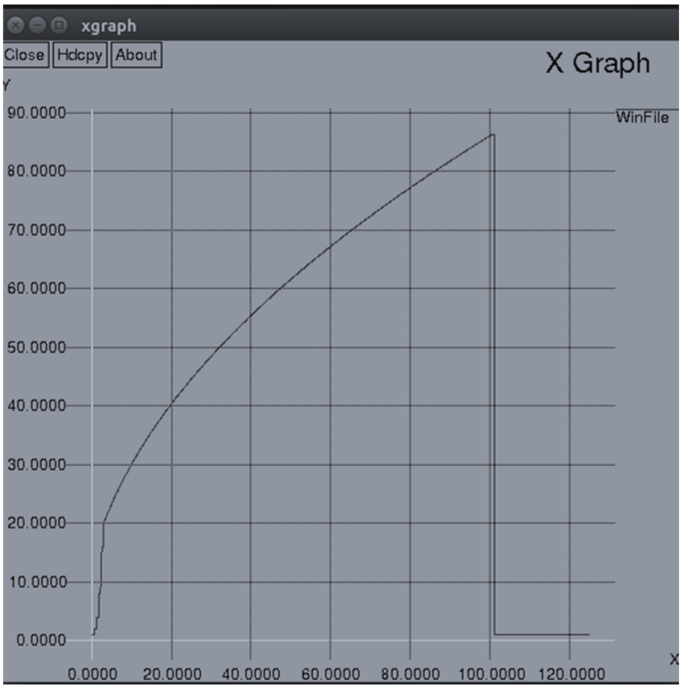


Figure 5. X graph of cwnd_ =0

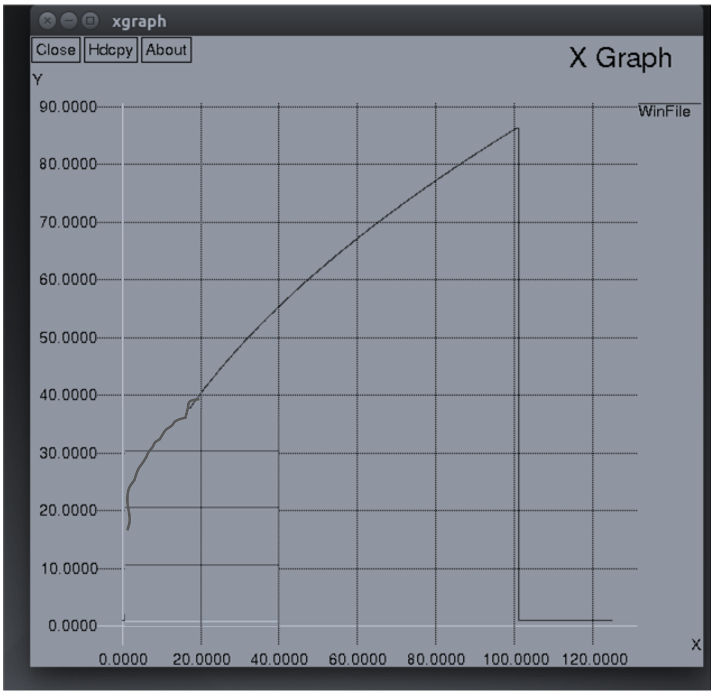


Figure 6. X graph of cwnd_ =5

3 Research Findings

Research findnings to be tested via the NS2 emulator in order to give us the test results. It is evident that with an increased congestion window in TCP, it enables quick transmission.

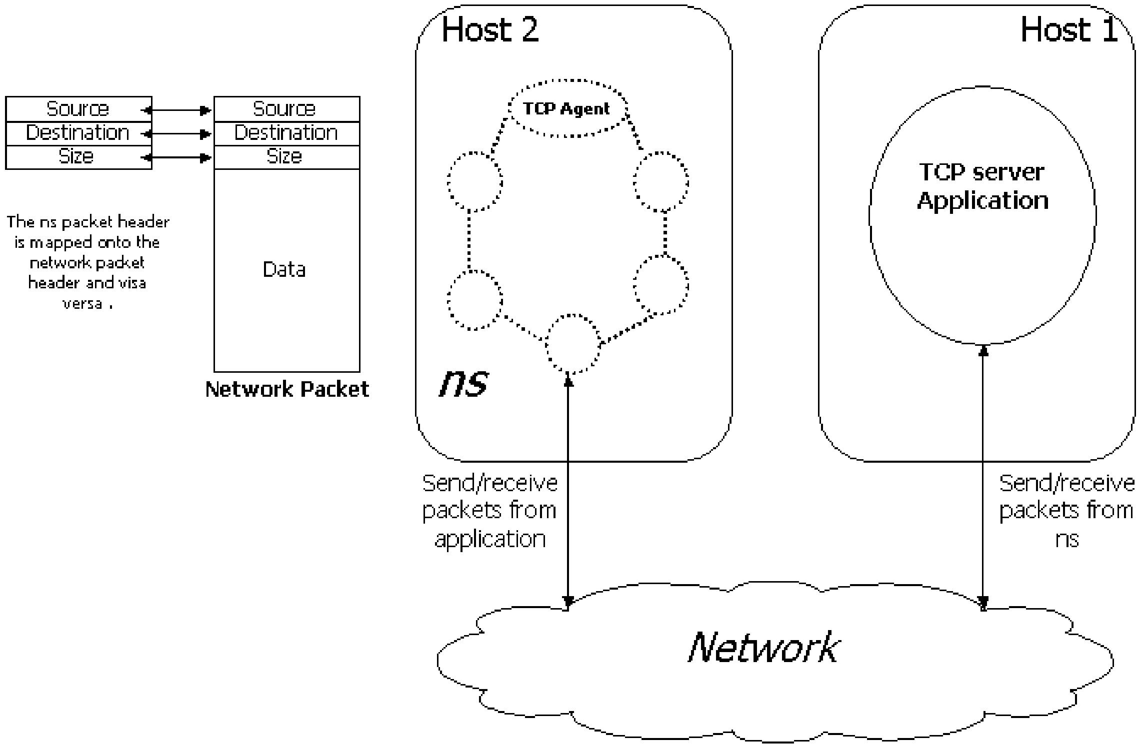
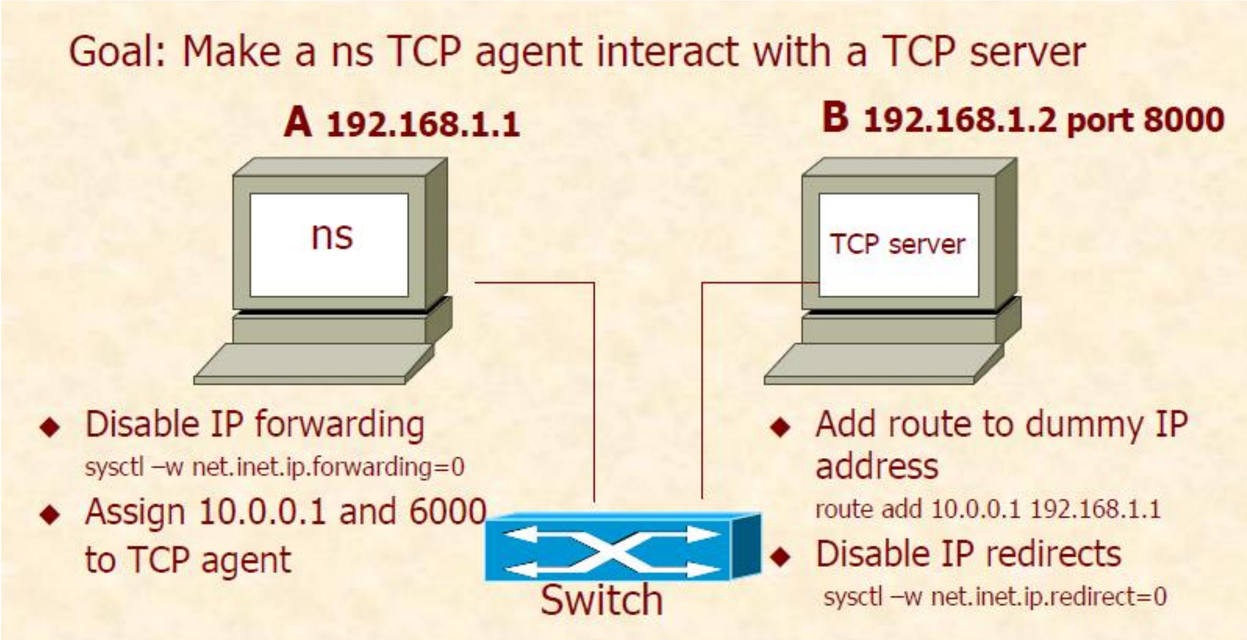


Figure 7. NS2 Emulation



Host Configuration

Figure 8. Emulating the updates to the TCP via the TCL script

3.1 Expected Advantages:

This feature to be included in the Proposed Dynamic TLP to accommodate our final outcome. Enabling faster transfers when it reads urgent data coming through it protocol.

4 Results and Discussion

5 Conclusion

As mentioned in the objectives, this research is to design and develop a dynamic Transport Layer (DTL) protocol, which is well suited for low latency, small payload data transfers or large data without the requirement of latency or combination two .Providing data transfer in a timely manner with the reliability will be very useful especially for the visually impaired to avoid dangerous situations such as file and change shore. This will be useful when the existing maps are changing or new roads are found. These changes should also transfer at one time or an appropriate event to the main system so it will help the next person coming in the same area.

This research identifies the specific data transfer behavior in CUCAT Application Way investigation that requires dynamic and efficient data transfers bounded time for small payloads. Due to the lack of support from existing transport layer protocols to facilitate all requirements of the way finding application, this research will be to continue the change process low latency transport the establishment connection layer, the bit sequence numbers variable and acknowledgment numbers, improved monitoring mechanism, improved congestion control mechanism in order to meet the requirements of the way finding application.

This research may also be important for other fields of application, such as medical systems. They have similar requirements, such as the transfer of the patient's vital signs (heart rate pulse , blood pressure and level of glucose in the blood) in real time, the delivery of large images (CAT scan, X -ray , etc.) and notes the low-priority patients.

6 References

[1]Dhammika H De Silva, Dr.Ian Murray “An investigation in to Dynamic TLP’s for Smartphone Communication”, in International Conference on Advances in ICT for emerging regions ICTer, 2013, p.194 – 197

[2]Haowei Bai *et al* “Impact of Mobile Wireless Links on TCP Performance”

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[4]Ibtissam El Khayat *et a*l “Improving TCP in wireless networks with an adaptive machine-learnt classifier of packet loss causes”

[5]Kunz.T et al “Transport Layer Fairness and Congestion Control in Multihop Wireless Networks”

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7 Appendix

Congestion control: A technique for monitoring network utilization and manipulating transmission or forwarding rates for data frames to keep traffic levels from overwhelming the network medium.

Mobile nodes: A node is either a connection point, a redistribution point communication endpoint

Packet loss: Packet loss is the failure of one or more transmitted packets to arrive at their destination. This event can cause noticeable effects in all types of digital communications

QoS: Quality of Service is the overall performance of a telephone or computer network, particularly the performance seen by the users of the network

Multi-hop: Multi-hop or ad hoc, wireless networks use two or more wireless hops to convey information from a source to a destination.

Wireless ad hoc networks: The ad hoc network does not rely on a pre-existing infrastructure, such as routers in wired networks or access points in managed (infrastructure) wireless networks. Instead, each node participates in routing by forwarding data for other nodes, so the determination of which nodes forward data is made dynamically on the basis of network connectivity.