UNIVERSITI PUTRA MALAYSIA

A SCALABLE RELIABLE MULTICAST TRANSPORT PROTOCOL WITH ADVANCED BUFFER MANAGEMENT

SAKHER AHMED AHMED HATEM

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Thesis Submitted to the School of Graduate Studies, Univesiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Doctor of Philosophy

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March 2016

Chairman : Mohd. Fadlee b. A.Rasid, PhD
Faculty : Engineering

Many reliable multicast transport protocols have been proposed to achieve efficient scalabilities and reliabilities in the field of multicast transmission. Tree-based reliable multicast schemes are one of those protocols, which divide the multicast tree into sub-trees and allocate a single node (known as repair node) in each sub-tree to do the task of loss packet recovery. The repair node, in each sub-tree is used to buffer and retransmit the loss packets. There is a great deal of problems in buffering packets waiting for a long time until they get positive acknowledgments from all children receivers of the repair node"s sub-tree. The problem gets even worse when the number of children receivers under the repair node increase over a certain limit or during heavy transmission. In that case, a buffer overflow will certainly occur which creates network congestion, also the throughput, scalability and in general, the performance of the system will be greatly decreased. This work introduces a new strategy based on distributing the burden of packets buffering and retransmission on a number of selected receivers (SRs) in each local group instead of entrusting this mission to only one node, the repair node. The proposed protocol, which is called, „The Selected Receiver Reliable Multicast Transport Protocol (or abbreviated to SRRMTP), is capable of solving the problems of buffering these packets waiting for positive acknowledgements. This distribution of the packets, can help in solving the congestion problem, increasing the network throughput, and decreasing the number of packets retransmitted from the source. Moreover, it can decrease the stability and latency time served, as well as distributing the burden of the resending process thereby increasing the protocol scalability. The proposed protocol is implemented over two environments; the first is the fixed network, and the second is the combined (fixed and mobile) network environments. Simulation using (C++) was performed to study and compare the performance of the proposed protocol with the previous protocols that have been based on the repair node strategy.

The results showed that the performances of the proposed protocol are better than the repair node protocols in terms of throughput, packet stability time and latency time, and packets retransmitted from the original sender. The proposed protocol was also more scalable than the repair node protocols in the case of the increment of the number of nodes in each local region or with an increment of the number of local regions in the multicast session.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PROTOKOL PENGANGKUTAN MULTISIAR YANG BERSKALA DAN DIPERCAYAI DENGAN PENGURUSAN PENIMBAL LANJUTAN

Oleh

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Banyak protocol yang dipercayai dalam pengangkutan multisiar telah dicadangkan untuk mencapai skala kecekapan dan kebolehpercayaan dalam bidang penghantaran multisiar. Berdasarkan pokok yang dipercayai dalam skema multisiar adalah salah satu protokol yang membahagikan multisiar pokok kepada sub-pokok dan memperuntukkan nod tunggal (dikenali sebagai nod pembaikan) dalam setiap sub-pokok untuk melakukan tugas pemulihan paket yang hilang. Dalam setiap sub-pokok, nod pembaikan telah digunakan untuk penampan dan menghantar semula paket yang hilang. Terdapat banyak masalah dalam paket penampan, yang mana mereka perlu menunggu untuk masa yang lama sehingga mereka menerima penghargaan yang positif daripada semua kanak-kanak peenerima sub-pokok nod pembaikan ini. Masalah menjadi semakin teruk apabila bilangan kanak-kanak penerima nod pembaikan meningkat melebihi had tertentu atau semasa penghantaran berat. Dalam keadaan ini, lebihan penampan akan berlaku sekaligus mewujudkan kesesakan rangkaian dan juga pemperosesan, keupayaan berskala dan umumnya persembahan sistem akan menurun. Tugasan ini akan memperkenalkan strategi baru berdasarkan pengedaran beban paket penampan dan penghantaran semula beberapa penerima terpilih (SRs) dalam setiap kumpulan tempatan dan kepercayaan misi ini bukan hanya kepada satu nod sahaja iaitu nod pembaikan. Protokol yang dicadangkan ini dipanggil sebagai „Penerima Protokol Pengangkutan yang Dipercayai oleh Multisiar Terpilih (atau singkatan kepada SRRMTP) di mana mampu menyelesaikan masalah-masalah penampan paket yang sedang menunggu penghargaan positif. Pengedaran paket ini boleh membantu dalam menyelesaikan masalah kesesakan, meningkatkan daya pemprosesan rangkaian, dan mengurangkan bilangan paket yang dihantar semula dari sumber. Selain itu, ia boleh mengurangkan kestabilan dan kependaman masa berkhidmat, serta masa pengedaran beban proses dihantar semula dengan itu meningkatkan protokol skala. Protokol yang dicadangkan dilaksanakan dalam dua persekitaran; yang pertama adalah rangkaian tetap, dan yang kedua adalah gabungan (tetap dan mudah alih) persekitaran rangkaian. Simulasi menggunakan (C++) telah ditunjukkan untuk mengkaji dan membandingkan prestasi protokol yang dicadangkan dengan protokol sebelumnya yang didasarkan oleh strategi nod pembaikan. Hasil kajian menunjukkan bahawa prestasi protokol yang

dicadangkan adalah lebih baik daripada protokol nod pembaikan dari segi pemprosesan, kestabilan paket dan kependaman masa, juga paket dihantar semula daripada penghantar asal. Protokol yang dicadangkan adalah lebih berskala daripada protokol nod pembaikan dalam kes kenaikan bilangan nod di setiap kawasan tempatan atau dengan kenaikan dalam sesi multisiar.

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I certify that a Thesis Examination Committee has met on 31 March 2016 to conduct the final examination of Sakher Ahmed Ahmed Hatem on his thesis entitled "A Scalable Reliable Multicast Transport Protocol with Advanced Buffer Management" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

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AARM	Adaptive and Active Reliable Multicast Protocol
ACK	Acknowledgment
AER	Active Error Recovery
AIM	Improving Internet Multicast
ARM	Active Reliable Multicast
ARMM	Agent for Reliable Mobile Multicast
ARP	Address Resolution Protocol
ARQ	Automatic Repeat reQuest
AWGN	Additive White Gaussian Noise
BGMP	Border Gateway Multicast Protocol
CBT	Core Based Tree
CMRE	Cache-Based Multicast Retransmission Encoding
CoA	Care-of Address
CR	Control Receiver
DA	Duplicate Avoidance
DFA	Domain Foreign Agent
DHARM	Dynamic Hybrid Active reliable Multicast
DHC	Dynamic Host Configuration Protocol
DLR	Designated Local Re-transmitter
DMRE	Dynamic Multicast Retransmission Encoding
DMSP	Designated Multicast Service Provider
DR	Designated Receiver
DVMRP	Distance Vector Multicast Routing Protocol
DyRAM	Dynamic Replier Active reliable Multicast
FA	Foreign Agent
FCRM	Flow Control Reliable Multicast
FEC	Forward Error Correction
FR	Fixed Receiver
FTP	File Transfer Protocol

HA	Home Agent
HTTP	Hypertext Transfer Protocol
IANA	Internet Assigned Numbers Authority
IETF	Internet Engineering Task Force
IGMP	Internet Group Management Protocol
IP	Internet Protocol
LAN	Local Area Network
LASTPKT	Last Packet
LMS	Light Multicast Services
LRMP	Lightweight Reliable Multicast Protocol
LRRM	Lightweight Randomized Reliable Multicast
MADCAP	Multicast Address Dynamic Client Allocation Protocol
MDP	Multicast Dissemination Protocol
MFTP	Multicast File Transfer Protocol
MH	Mobile host
MMP	Multicast for Mobility Protocols
MOSPF	Multicast Extension for Open Shortest Path First
MTP	Multicast Transport Protocol
NACK	Negative Acknowledgment
NAPP	Negative Acknowledge with Periodic Polling
NCF	NACK Confirmation
NE	Network Elements
NORM	NACK-Oriented Reliable Multicast
OSPF	Open Shortest Path First Routing Protocol
PGM	Pragmatic General Multicast
PIM	Protocol Independent Multicast
PIM-DM	Protocol Independent Multicast - Dense Mode
PRMA	Packet Reservation Multiple Access
QoS	Quality-of-Service
RAMP	Reliable Adaptive Multicast Protocol
RBMoM	Rang- Based Mobile Multicast

RIP-2	Routing Information Protocol version 2
RM	Reliable Multicast
RMDP	Reliable Multicast Data Distribution Protocol
RMP	Reliable Multicast Protocol
RMTP	Reliable Multicast Transport Protocol
RP	Rendezvous Point
RRMP	Randomized Reliable Multicast Protocol
RS	Retransmission Servers
RTT	Round Trip Time
SCE	Single Connection Emulation
SMTP	Simple Mail Transfer Protocol
SNR	Signal-to-Noise Ratio
SR	Selected Receiver
SRM	Scalable Reliable Multicast
SRRMTP	Selected Receivers Reliable Multicast Transport Protocol
SRRS	Server Relay Recovery Strategy
TCP	Transport Control Protocol
TELNET	TCP/IP Terminal Emulation Protocol
TMTP	Tree-Based Multicast Transport Protocol
TRACK	Tree-Based Acknowledgment
TRAM	A Tree-based Reliable Multicast Protocol
TRM	Transport Protocol for Reliable Multicast
UDP	User Datagram Protocol

CHAPTER 1

INTRODUCTION AND BACKGROUND OF THE STUDY

1.1 Introduction

Multicasting provides an efficient way of disseminating data from a sender to a group of receivers instead of sending a separate copy to each individual receiver. A multicast tree is set up in the network with the sender as the root and the receiver as the leaf nodes. Data generated by the sender flows through the multicast tree, traversing each tree edge exactly once. However, distribution of data using the multicast tree in an unreliable network does not guarantee reliable delivery, which is the prime requirement for several applications. Many researchers have proposed several protocols to achieve the reliable delivery of packets. Tree-based reliable multicast schemes are some of the most proposed protocols, which divide the multicast tree into sub-trees and allocate a repair node in each sub-tree to do the task of loss packet recovery. This way of recovery faces many challenges like implosion, congestion, scalability, and buffer managements.

The present study has set out to examine and solve the problem facing the buffer management of the tree-based reliable multicast protocols, which are used for wired and wireless networks. The goal of this research is to mitigate the problems of buffer management by proposing a new protocol that has an improved buffer management by distributing the buffering of the requested packets that might be required to be retransmitted between some selected receivers that have previously received these packets correctly. In this research, a new algorithm based on a control receiver (CR) has been proposed to provide a solution for the buffer management problem. This algorithm is referred to as “Selected Receivers Reliable Multicast Transport Protocol (SRRMTP)”. The idea behind this protocol is to distribute the burden of the buffering of the requested packets, between the selected receivers located on the local region instead of having this mission performed by only one repair node. The authors have compared the proposed protocol with previous protocols and the results showed that the proposed protocol out performs the previous protocols in terms of scalability, packets resent for the source, stability and latency time, throughput and the available window.

The performance of the proposed protocol has been tested and evaluated over two environments, which were a fixed network and a combined network (fixed and mobile). Moreover, the performance of the previous protocols has been tested and evaluated using simulation for validation and comparison purposes. This research has implemented the network by using the visual C++ language simulation programme.

1.2 Background of the Study

As telecommunication systems continue to evolve, it is envisaged that regardless of one's location, individuals will be able to transmit voice, data and video to any other person in the world through wireless-based communication. It is also expected that instead of disparate wireless systems and technologies being required for each type of information, there should be a single and integrated system that serves for the unique requirements of each type of information. Such an improved system would not only be capable of delivering a wide range of services, but would also provide these services to a large number of users in an efficient, accurate, and timely manner.

In order to serve a large number of users who are demanding the same data, it is more efficient to transmit this data using multicast transmission. Multicasting is a network-efficient technique for distributing information to a large group of receivers. In multicasting, the sender of the information can transmit a single copy of each packet without knowing the recipients. However, the minimisation of bandwidth consumption is possible since only a single copy of a multicast packet flows over each link and intermediate routers. The responsibility of managing the multicast group is on the receivers instead of the sender based on the difficulty being encountered by the sender to maintain the size and membership state of the high growing rate of the group as receivers who are interested in receiving the data do frequently join the multicast group.

In a multicast network, there is a need for a multicast tree to be set up in which the sender serves as the root node whilst the receivers serve as the leaf nodes. The data generated by the sender flows through the multicast tree thereby traversing each edge only once. However, the idea of disseminating the data using the multicast tree in a network is not guaranteed reliable delivery. Reliable delivery is one of the prime requirements in some kinds of services in a multicast network. A reliable multicast network ensures that every data packet from a source is delivered correctly to all receivers of a multicast group.

An end-to-end control mechanism, like TCP in unicast transmissions, is not applicable for IP multicasting based on the fact that it is the feedback of all the control information in the multicast network from the receivers to a single sender thereby causing a burst of traffic towards the sender. Therefore, a specialised transport layer protocol must be defined to deal with the challenges of end-to-end reliability, such as buffer management, congestion, implosion, flow control, low latency, scalability, and efficient bandwidth problems. Many researchers have proposed different mechanisms and protocols to mitigate such challenges.

Amongst the several proposals proposed by researchers were Repair Nodes protocols, which divided the multicast tree into sub-trees and allocated a repair node in each sub-tree. The goal of these repair nodes is to integrate the status of the information of their receivers and perform local error recovery for these receivers using the data stored in their buffers. Earlier researchers proposed protocols that used positive acknowledgment (ACK) schemes for tree-based mechanisms (Lin & Paul 1996; Paul et al. 1997; Guo & Rhee 2000; Kadansky et al. 2000; Saikia & Hemachandran 2009).

However, such schemes of control mechanisms suffer from buffer congestion due to the problem of the slowest receivers, which force repair nodes to keep packets for a long time in its buffers.

Furthermore, other researchers that have focused on other control mechanisms proposed a negative acknowledgment-based (NACK-based) system. A NACK-based system is supposed to solve the problem of implosion by moving error detection tasks from the repair node to each receiver node where only the receivers which are facing loss packets need to send an acknowledgment (Floyd et al. 1997; Yamamoto et al. 1997; Birman et al. 1999; Costello & McCanne 1999).

The drawback of the NACK-based protocols is that there is no efficient mechanism to safely discard packets from the repair node buffers because they do not guarantee that the packets have been received correctly. This leaves the repair nodes with a difficult choice. They can either work on the safety side by keeping in their buffer the packets that have already been correctly received by all nodes or discard requested packets.

In addition, the Scalable Reliable Multicast (SRM) is a well-known receiver-initiated multicast protocol that guarantees out-of-order reliable delivery using NACKs from its receivers. This indicates that whenever a receiver detects a loss packet, NACK, which is multicast to all the participants in the multicast session, allows the nearest receiver to retransmit the packet by multicasting. Thereby, the distributions of the error recovery load from one sender to all receivers of the multicast session is achieved (Floyd et al. 1997; Costello & McCanne 1999; Ozkasap et al. 1999) (Daescu et al. 2003; Daescu et al. 2004). However, such schemes do not provide efficient mechanisms to discard the packets from the repair node buffers safely because it does not guarantee that the packets sent have been received correctly.

Other protocols try to mitigate the buffering problem by using both positive and negative acknowledgements (ACK+NACK) to get a trade-off between buffer management and ACK implosion. However, such proposals still have drawbacks because they suffer from positive and negative acknowledgement scheme disadvantages (Baek & Paris 2004; Baek & Paris 2005; Chourishi & Seshadri 2009). In general, the previous researches that focused on positive acknowledgement (ACK) or negative acknowledgement (NACK) or combining both depended only on the buffers of the repair nodes to save the packets that might have been required for retransmission, which would increase the network congestion.

In this research, a new algorithm model based on both fixed networks and hybrid fixed and mobile networks to provide a solution of the buffer management problem has been proposed. This proposed algorithm-based model is known as the ‘Selected Receivers Reliable Multicast Transport Protocol’ (hereafter referred to as SRRMTP). The goal of SRRMTP is to solve the problem of saving and retransmission of the requested packets. Thus, it is expected that this algorithm-based model would solve the problem of saving and retransmission of the requested packets by distributing these packets between some selected receivers’ buffers that have previously received these packets correctly. This distribution decreases the number of packets congested in the buffer of the repair node. As a result, this method can solve the congestion problem and increases the network throughput. Moreover, the suggested protocol in this research helps in reducing the overhead upon the repair nodes by easing the burden of the retransmission of the loss packets amongst the selected receivers.

Furthermore, the model is expected to provide the fast recovery of loss packets because the recovery is carried out between the receivers in the same local region, which decreases the packets stability time, which makes the protocol suitable for real time multicasting applications. The proposed protocol provides an efficient buffer management scheme, which reduces the retransmission of packets from the sender thereby, enhancing bandwidth utilisation. In addition, this proposal has more advantages over other schemes. Amongst these advantages is its ability to avoid the problem of a “crying baby” by saving the requested packets of the crying receiver in the buffers of the nearest receivers. The “crying baby” problem appears if one or a few receivers experiencing high packet loss triggers repeated retransmission and slows down the entire multicast session.

Thus, this research consists of two parts as discussed. The first part is the implementation of the proposed protocol over the fixed network environment. The second part is the implementation over the hybrid of both fixed and mobile network environments of which some of the receivers are fixed and other receivers are mobile hosts (MHs). These fixed networks represent the wire line part of the network. On the other hand, MH receivers represent the wireless part of the network.

1.3 Problem Statement

The three-based reliable multicast protocols divided the multicast tree into sub-trees which are called local regions, and the protocols allocated a single node in each sub-tree to do the task of buffering and retransmitting the packets that maybe loss in some receivers, these nodes are called repair nodes or designated receivers. These repair nodes/designated receivers face problems in retransmitting and buffering packets waiting for a long time until they get positive acknowledgments from all the children receivers of the repair node’s local region. The problem gets even worse when:

The number of children receivers under the repair node increases over a certain limit. In the case of high loss probability of any link of the session which causes an increase in the number of packets loss.

Crying baby happens which prevents it from receiving packets and consequently, forces its repair node to buffer those packets until this receiver recovers.

In any of those cases, a buffer overflow will certainly occur which creates network congestion; also, the bandwidth utilization and the packets being retransmitted from the original sender increases. In addition, the throughput, scalability, average stability time, recovery time and in general, the performance of the system will be greatly decreased. This work introduces a new strategy based on distributing the burden of packet buffering and retransmission onto a number of selected receivers (SRs) in each local group to solve such problems be faced.

1.4 Research Objectives

The main objectives of this research are:

1. To decrease the number of packets which are resent from the original sender by making an error recovery between the receivers in the same local group.
2. To decrease the stability time and the latency time by improving the strategy of the packet recovery and retransmission.
3. To improve the throughput of the tree-based multicast protocols by increasing the average available window.
4. To increase the scalability of the tree-based reliable protocols to serve more nodes.
5. To solve the problem of packet congestion in the repair nodes by moving the burden of buffering to the child receivers.
6. To provide a strong tree-based reliable multicast protocol with an efficient buffer management by solving the problems that are facing the buffer managements.

1.5 Research Justifications

The justifications for advancing the newly proposed protocol based on the SRRMTP protocol is to test and solve the problems facing the reliable multicast protocols, such as the buffer management problem, scalability, crying baby, packet requested from the original source, duplicate packets, available window, and the overhead of the repair nodes. The idea behind proposing the new protocol based on SRRMTP is to move the burden of saving and retransmitting the lost packets from one node, which is the repair node, to many nodes, which are the selected receivers in the same local group. The process of such a move will be able to provide a strong buffer management because the requested packet for retransmission can be saved in many buffers in the local region so that the congestion problem that appears when using only one node to save all requested packets is solved. Moreover, the retransmission of the loss packets will become easier because it can be performed through many nodes in the same local region.

The number of packets requested to be retransmitted from the original sender becomes very low compared with the previous protocols that have used the repair nodes because the methods of data recovering in this study are performed through many nodes which are known as selected receivers (SRs). This scheme, which depends on many nodes to recover the loss packets, gives a higher chance in finding the loss packets in their buffers. The operation of the proposed protocol greatly reduces the overhead on the original sender, saves the bandwidth and reduces the duplicated packets resulting if otherwise the original sender retransmits the loss packets to all the receivers when the number of requested receivers is greater than the threshold number. However, the previous protocols depend only on one node in each local group to recover the loss packets; this node is referred to as the repair node. The repair node requests any loss packets directly from the original sender if it is not available in its buffer, which increases the number of duplicated packets and bandwidth consumption.

The proposed protocol also increases the number of new packets that can be transmitted in each sending period, available window, by distributing the buffering of the packets that might be requested for retransmission amongst several selected receivers. Previous protocols using some other strategies like the sliding window mechanism (Whetten & Taskale 2000) (Paul et al. 1997; Daescu et al. 2003; Daescu et al. 2004) and the replacement window (Alsaih 2009) all depend on one node to buffer the packets that might be requested for retransmission, which results in decreasing the available window.

1.6 Contributions of the Thesis

The current proposed protocol, which is based on a scalable receiver reliable multicast protocol (SRRMTP), was designed to solve the problems facing the reliable multicast protocols like the buffer management problem, scalability, crying baby, packet requested from the original source, duplicate packets, and available window. In order to evaluate the model, the model was tested against protocols in the literature, which included design receivers (DRs) and repair nodes to recover loss packets. The idea behind proposing the new protocol based on the scalable receiver reliable multicast protocol (SRRMTP) model was to move the burden of saving and retransmitting the loss packets from one node, which is the repair node, to many nodes, which is the selected receiver for the same local group. Such a move proved effective by providing a strong buffer management because the requested packet for retransmission can be saved in many buffers in a local region so that the congestion problem that appeared when using only one node to save all requested packets can be solved. Moreover, the retransmission of the loss packets becomes easier because it should be performed through many nodes in the same local region.

The main objectives of this research can be summarised as below:

The idea behind proposing the new protocol based on the SRRMTP is to move the burden of saving and retransmitting of the loss packets from one node (the repair node) to many nodes that have been selected as selected receivers (SRs) in the same local group. This moving provides a better buffer management because the packets that might be requested for retransmission are saved in many buffers in a local region. This in turn will reduce the congestion problem that otherwise will appear when using only one node to save such packets. Moreover, the retransmission of the loss packets becomes easier because it can be performed through many nodes in the same local region instead of only one repair node as in the previous protocols.

1.6.1 Reduce the Number of Packets Requested for Retransmission from the Source

The number of packets requested to be retransmitted from the original source becomes very small, which is very low comparing with the previous protocols which use the repair nodes because data recovering in this study is performed through many nodes known as "CRs". This scheme depends on many nodes to recover loss packets, which provides a high chance to find the loss packets in their buffers. Mean whilst, the previous protocols depend only on one node in each local group to recover the loss packets; this node is referred to as the repair node. The repair node requests any loss packets directly from the original sender if it is not available in its buffer.

This contribution reduces the overhead on the original sender, saves the bandwidth and reduces the number of duplicated packets that happens when the sender retransmits the loss packets by multicasting to all receivers when the number of receivers that request the same packets is greater than the threshold number.

1.6.2 Improve Network Scalability

By distributing the packets that might be requested for retransmission between many CRs, instead of one repair node as in the previous protocols, the tree-based network scalability will improve to serve a great deal of receivers. The scalability will be improved because the new strategy allows each CR in each local group to manage the recovering of loss packets locally without bothering the source to send them. In this case, the proposed protocol changes the way of recovering from a centralised strategy that depends mainly on the repair nodes and the source to a distributed strategy that depends on many selected receivers in each local group. Moreover, this contribution also reduces the stability and latency time because of the strategy just described.

1.6.3 Increase the Network Throughput

The network throughput is increased by increasing the average available window, which is the number of packets that can be sent in each sending period. In the previous Reliable Multicast Transport Protocols which use the DRs or repair nodes to recover loss packets (Paul et al. 1997; Pradip & Ali 2010), the sender uses the sliding window protocol where the sender slides the window and increases the available window size after the packet that has the smallest sequence number becomes stable. This type of technique has a disadvantage because many times other packets that have greater sequence numbers become stable before this packet and in this case, the sender does not increase the available window.

The protocol in this research overcomes such a disadvantage by distributing the buffering of the requested packets between some SRs instead of saving them in one node, the repair node.

Each local region has only one repair node but it can select many receivers to save and resend the requested packets. Calculating the available window in the proposed protocol depends on the SR buffers and not on the repair node buffers.

1.6.4 Solve the Crying Baby Problem

The last contribution from the suggested protocol in this thesis is to solve the crying baby problem. This problem occurs when any of the receivers facing a high packet lost may trigger repeated retransmission and slow down the entire multicast session. The proposed protocol solves such problems by saving the packets requested for the crying baby in the nearest SRs and makes it responsible for recovering the loss packets. This is unlike the protocols proposed in the literature, in which the packet recovery is the sole responsibility of the repair node. Thus, in their proposals, in order to recover the lost packets of the crying baby, the repair node should keep those entire packets in its buffer, which badly decreases the next available window.

1.7 Organisation of the Thesis

This dissertation is presented in six chapters. Chapter I of this research has presented the introduction and the contributions of this research as well as the overview of the entire work. Chapter II present a background, definition and explanation of the concepts of IP multicast, the relevant background research, which includes the. The multicast in wireless environments and protocol approaches also discussed in chapter II. Chapter III explained the reliable multicast protocols in wireless and wire-line networks. And also reviewed the classes of reliable multicast and the challenges facing reliable multicast. Finally, a survey of the related work to the proposed protocol and an introduction to the Tree-based Reliable Multicast Protocol are presented in chapter III.

Chapter IV focuses on the methodology of the proposed protocol which includes the protocol details, protocol entities and explains in detail the design and processing of the proposed protocol.

Chapter V presents the simulation of the proposed protocol over a fixed network environment and the results of the fixed environment network are also discussed in chapter IV. Whilst chapter VI starts with an introduction to the mobile networks and then focuses on the simulation of the proposed protocol over hybrid (fixed and mobile) network environments. Finally, chapter VI also explains and discusses the results of the implementation of the proposed protocol over the hybrid network environments and compares that result with the previous protocols' results. Chapter VII presents the conclusions and discusses future extension of this work and proposals for future works.

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