

Enhanced Controlled Flooding (ECF)

Routing Algorithm

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ملخص

خوارزميات التوجيه الهيكلية "Hierarchical Routing Algorithms" تعاني من عدة مشاكل، من أهم هذه المشاكل إيجاد الطريق بين المرسل و المستقبل في منطقتين مختلفتين من الشبكة ذات أقل تأخير في الوقت "least delay time"، والهدف الرئيس من هذا البحث محاولة استخلاص الحسنات الموجودة في كل من تقنية التوجيه الهيكلية "hierarchical" وتقنية توجيه الفيضان "flooding" وتكون النتائج في نقل البيانات تتصف بالدقة والفاعلية والمرونة.

في هذا البحث "Enhanced Controlled Flooding routing algorithm ECF"، يقترح تصنيف العقد "nodes" في شبكات الحاسوب إلى صنفين هما: عقدة اعتيادية "ordinary"، عقدة تحكم "control"، وهذه الخوارزمية تستخدم ثلاثة أنواع من حزم نقل البيانات وهي: "حزم فيضان، حزم طلب، وحزم رد" من أجل التحكم بعمل الخوارزمية، وهو مقسم إلى جزأين، الأول وهو جزء استقبال الحزم وهو يعمل في جميع أنواع العقد، أما الثاني وهو جزء الإرسال وهو ينفذ فقط في العقد الاعتيادية. في النهاية، توصل الباحث من خلال أمثلة مرفقة -عرض توضيحي متحرك- أن الحل المقترح قلل وقت التأخير في نقل البيانات بين عقدتين موجودتين في مناطق مختلفة في الشبكة (وهذه هي أهم مساوئ التوجيه الهيكلية).

Abstract

Hierarchical routing algorithms suffer from many problems. One those problems are that the researcher takes the problem of finding the least delay time path between the source node and destination node in different regions. The research's main design goals are accuracy, scalability and efficiency, so the researcher tries to obtain most of the advantages from both hierarchical and flooding techniques.

In this research the Enhanced Controlled Flooding (ECF) routing algorithm is proposed, that classifies network nodes into two kinds, ordinary and control node. Also the ECF uses three packet types (flooding, request and reply) to control its work, which is divided into two parts, the first one that is ECF Flooding Receive Part is acted in all node kinds, whereas the other part that is ECF Sending Part is only acted in the ordinary nodes.

Finally, the researcher finds out through the examined examples –animation demo— that this proposed solution solves the least delay time between two nodes in different regions (one of hierarchical routing disadvantages).

Acknowledgements

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Chapter 1

Introduction

Nowadays, networks are the backbone of the world, since all life fields depends on to carry out life needs such as e-learning, e-shopping, e-business ...etc.

1.1 Network Overview

Network can be defined as a group of two or more computer systems linked together, where it provide the ability to communicate with each other. See figure(1.1).

Another definition of Computer Network “is a collection of autonomous computers interconnected by a single technology” 0. Whereas Internetwork is connecting of two or more networks. For the purpose of this research we will use network and innetwork interchangeable to mean the same thing.

There are many types of computer networks, including:

Local Area Networks (LANs): The computers are geographically close together (that is, in the same building).

Wide Area Networks (WANs): The computers are farther apart and are connected by telephone lines or radio waves.

Campus Area Networks (CANs): The computers are within a limited geographic area, such as a campus or military base.

Metropolitan Area Networks (MANs): A data network designed for a town or city.

Home Area Networks (HANs): A network contained within a user's home that connects a person's digital devices.

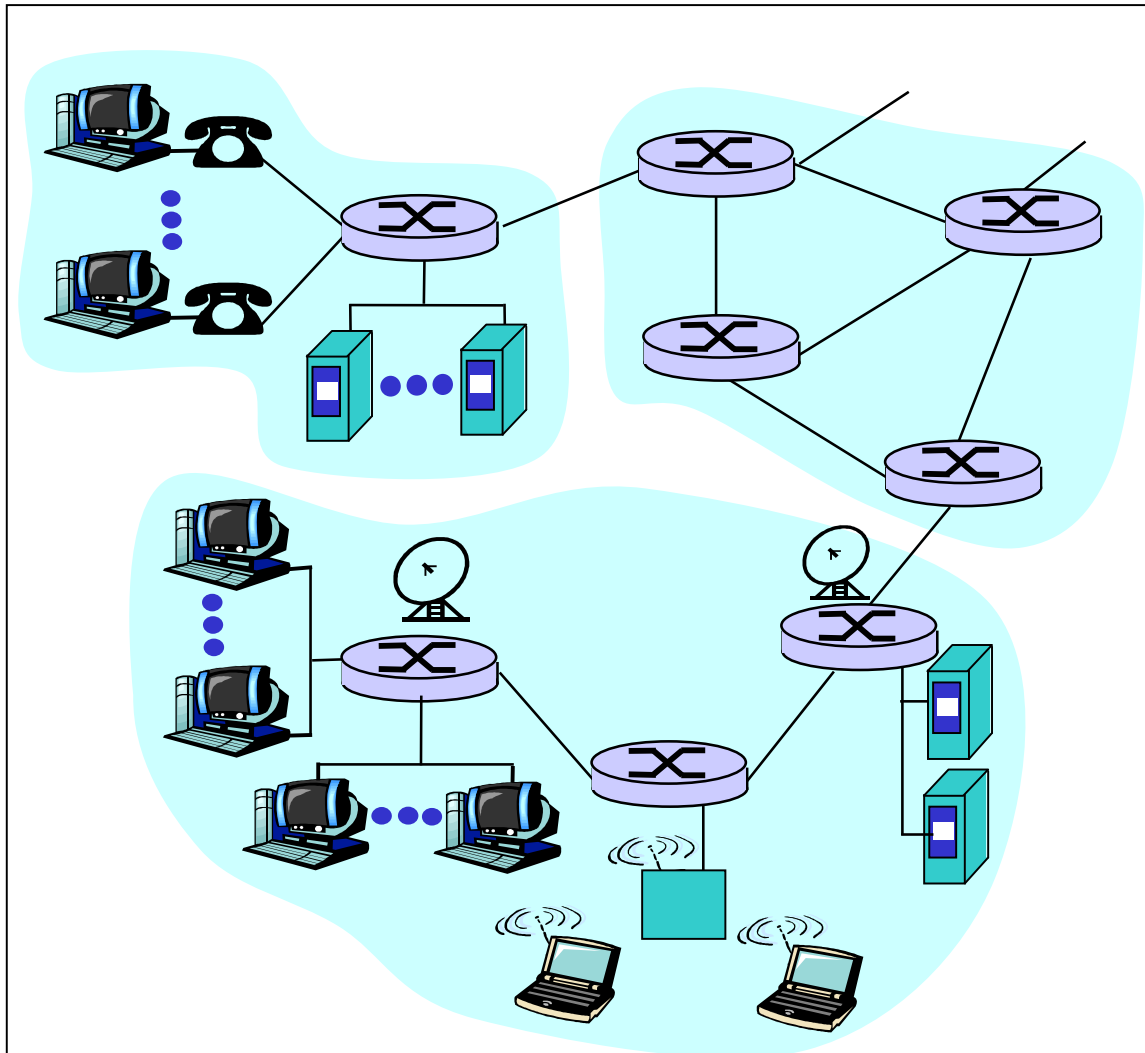


Figure 1.1: General Networks Preview

In addition to these types, the following characteristics are also used to categorize different types of networks:

Topology: The geometric arrangement of a computer system. Common topologies include a bus, star, and ring.

Protocol: The protocol defines a common set of rules and signals that computers on the network use to communicate.

Architecture: Networks can be broadly classified as using either a peer-to-peer or client/server architecture.

Generally Networks devices can be divided into two kinds, devices that generate signal (packet) such as computers, where the other kind is responsible of carry, distribute and route the signal, such as (Hub, Switch, Bridge and Router).

1.2 Network Layer

In the Open Systems Interconnection (OSI) communications model, the Network layer knows the address of the neighboring nodes in the network, packages output with the correct network address information, selects routes and Quality of Service, and recognizes and forwards to the Transport layer incoming messages for local host domains00.

The network layer – third layer in OSI model as shown in figure (1.2) - is concerned with controlling the operation of the subnet. A key design issue is determining how packets are routed from source to destination. Routes could be based on static tables that are wired into the network and rarely changed. They could also be determined at the start of each conversation, for example a terminal session. Finally, they could be highly dynamic, being determined anew for each packet, to reflect the current network load 00.

7	Application
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6	Presentation
5	Session
4	Transport
3	Network
2	Data Link
1	Physical

Figure 1.2: The OSI Reference Model Contains Seven Independent Layers

When a packet has to travel from one network to another to get to its destination, many problems can arise. The addressing used by the second network may be different from the first one. The second one may not accept the packet at all because it is too large. The protocols may differ, and so on. It is up to the network layer to overcome all these problems to allow heterogeneous networks to be interconnected. If too many packets are present in the subnet at the same time, they will get in each other's way, forming bottlenecks. The control of such congestion also belongs to the network layer.

Networks can be classified according to many characteristics, such transmission technology where networks divided to broadcast, multicast and unicast networks. In broadcast networks, the routing problem is simple, so the network layer is often thin or even nonexistent. In contrast the network layer plays a great deal in point to point (unicast networks).

So the most important component of network layer software part is the routing algorithms where this research is concerned with.

1.3 Routers and Routing Algorithms

Routers use routing algorithms to find the best route to a destination as simply shown in figure (1.3). When we say "best route," we consider parameters like the number of hops (the trip a packet takes from one router or intermediate point to another in the network), time delay and communication cost of packet transmission 0000.

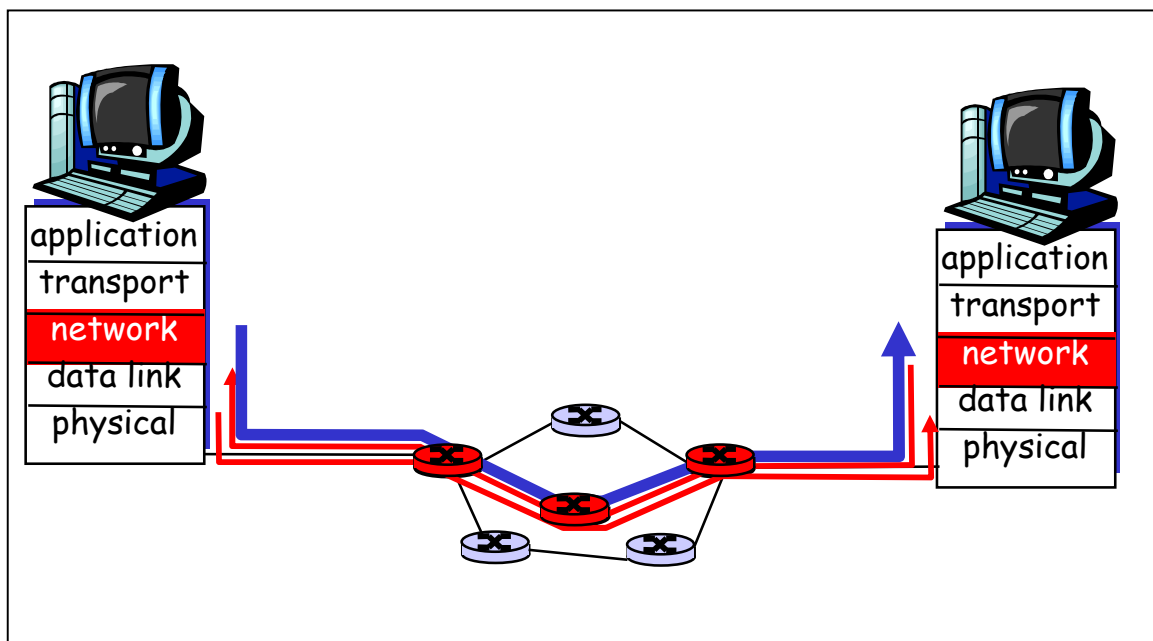


Figure 1.3: Simple Routing idea.

The topic of routing has been covered in computer science literature for more than two decades, but routing achieved commercial popularity as late as the mid-1980s. The primary reason for this time lag is that networks in the 1970s were simple,

homogeneous environments. Only relatively recently has large-scale internetworking become popular.

Nowadays, routing algorithms have many classification based on how routers gather information about the structure of a network and their analysis of information to specify the best route. Such as (static or dynamic, flat or hierarchical, link state or distance vector ...etc).

Routing algorithms depend on many metrics such as (path length, reliability, delay, bandwidth, load, communication cost) to perform their works, taking in consideration achieve as much as possible of the desired properties. We will cover all the previous topics in details in chapter 2

1.4 Future of Networks

Networks have been involved into many life fields, which lead to a huge expansion in terms of size and node number. Also there is a great revolution in network devices. All these lead to create new demands such as improve services quality and offer new services, which mean we need to improve and enhance the routing techniques.

Also, there is a lot of work to be done to enhance the routing techniques used in wireless networks.

1.5 In This Research

The researcher tries to solve one of the most popular hierarchical routing algorithms disadvantages, that is finding the least delay time between two nodes (research problem), which reside in different regions.

This research aims at trying to prove by explanation and animation demo – attached with research— that the proposed solution (ECF routing algorithm) has succeeded in solving the problem of this research.

The research is composed of four chapters. Chapter 1 introduces networks; overview of networks, network layer, routers and routing algorithms, and the future of networks. Chapter 2 discusses the routing algorithms in details, and is concerned with the way how routing algorithms work. The routing algorithms classification and the desirable properties in routing algorithms are also covered. After that, two important routing algorithms (Flooding and hierarchical routing algorithms) are discussed, including the most used routing metrics. The proposed ECF routing algorithm and it's two parts – which are developed by the researcher— are explained in chapter 3. Finally, the researcher concludes the research in chapter 4.

Chapter 2

Routing algorithms

2.1 What Is Routing?

The process of moving packet of data from source to destination. Routing is usually performed by a dedicated device called a router. Routing is a key feature of the Internet because it enables messages to pass from one computer to another and eventually reach the target machine. Each intermediary computer performs routing by passing along the message to the next computer. Part of this process involves analyzing a routing table to determine the best path 00.

2.2 Routing Processes

The IP routing processes on all nodes involved in the delivery of an IP packet includes: the sending host, the intermediate routers, and the destination host 0.

2.2.1 IP on the Sending Host

When a packet is sent by a sending host, the packet is handed from an upper layer protocol (TCP, UDP, or ICMP) to IP. IP on the sending host does the following:

Sets the Time-to-Live (TTL) value to either a default or application-specified value.

IP checks its routing table for the best route to the destination IP address.

If no route is found, IP indicates a routing error to the upper layer protocol (TCP, UDP, or ICMP).

Based on the most specific route, IP determines the forwarding IP address and the interface to be used for forwarding the packet.

IP hands the packet, the forwarding IP address, and the interface to Address Resolution Protocol (ARP), and then ARP resolves the forwarding IP address to its media access control (MAC) address and forwards the packet.

2.2.2 IP on the Router

When a packet is received at a router, the packet is passed to IP. IP on the router does the following:

IP verifies the IP header checksum.

If the IP header checksum fails, the IP packet is discarded without notification to the user. This is known as a *silent discard*.

IP verifies whether the destination IP address in the IP datagram corresponds to an IP address assigned to a router interface.

If so, the router processes the IP datagram as the destination host (see step 3 in the following "IP on the Destination Host" section).

If the destination IP address is not the router, IP decreases the time-to-live (TTL) by 1.

If the TTL is 0, the router discards the packet and sends an ICMP Time Expired-TTL Expired message to the sender.

If the TTL is 1 or greater, IP updates the TTL field and calculates a new IP header checksum.

IP checks its routing table for the best route to the destination IP address in the IP datagram.

If no route is found, the router discards the packet and sends an ICMP Destination Unreachable-Network Unreachable message to the sender.

Based on the best route found, IP determines the forwarding IP address and the interface to be used for forwarding the packet.

IP hands the packet, the forwarding IP address, and the interface to ARP, and then ARP forwards the packet to the appropriate MAC address.

This entire process is repeated at each router in the path between the source and destination host.

2.2.3 IP on the Destination Host

When a packet is received at the destination host, it is passed up to IP. IP on the destination host does the following:

IP verifies the IP header checksum.

If the IP header checksum fails, the IP packet is silently discarded.

IP verifies that the destination IP address in the IP datagram corresponds to an IP address assigned to the host.

If the destination IP address is not assigned to the host, the IP packet is silently discarded.

Based on the IP protocol field, IP passes the IP datagram without the IP header to the appropriate upper-level protocol.

If the protocol does not exist, ICMP sends a Destination Unreachable-Protocol Unreachable message back to the sender.

For TCP and UDP packets, the destination port is checked and the TCP segment or UDP header is processed.

If no application exists for the UDP port number, ICMP sends a Destination Unreachable-Port Unreachable message back to the sender. If no application exists for the TCP port number, TCP sends a Connection Reset segment back to the sender.

How routing algorithms work

The routing algorithm is that part of the network layer software responsible for deciding which output line an incoming packet should be transmitted on.

Routing algorithm is responsible for filling in and updating the routing tables which will be referred by forwarding process where each packet as it arrives, looking up the outgoing line to use for it in the routing tables.

Routers use routing algorithms to find the best route to a destination. When we say "best route," we consider parameters like the number of hops, time delay and communication cost of packet transmission.

There are many types of routing algorithms which are differed from each other in many aspects like routing table construction, information gathering, and other variables which leads to many routing algorithms classifications.

Routing algorithm classifications

Routing algorithms can be classified as follow:

Static or Dynamic

Flat or Hierarchical

Link State or Distance Vector

2.4.1 Static or Dynamic

Static routing algorithms are hardly algorithms at all. Static routing table mappings are established by the network administrator prior to the beginning of routing. They do not change unless the network administrator changes them. Algorithms

that use static routes are simple to design and work well in environments where network traffic is relatively predictable and network design is relatively simple.

Because static routing systems cannot react to network changes, they are generally considered unsuitable for today's large, constantly changing networks. Most of the dominant routing algorithms in the 1990s are dynamic.

Dynamic routing algorithms adjust, in real time, to changing network circumstances. They do this by analyzing incoming routing update messages. If the message indicates that a network change has occurred, the routing software recalculates routes and sends out new routing update messages. These messages permeate the network, stimulating routers to rerun their algorithms and change their routing tables accordingly.

Dynamic routing algorithms may be supplemented with static routes where appropriate. For example, a router of last resort (a router to which all unroutable packets are sent) may be designated. This router acts as a repository for all unroutable packets, ensuring that all messages are at least handled in some way.

2.4.2 Flat or Hierarchical

Some routing algorithms operate in a flat space, while others use routing hierarchies. In a flat routing system, all routers are peers of all others. In a hierarchical routing system, some routers form what amounts to a routing backbone. Packets from non-backbone routers travel to the backbone routers, where they are sent through the backbone until they reach the general area of the

destination. At this point, they travel from the last backbone router through one or more non-backbone routers to the final destination.

Routing systems often designate logical groups of nodes called domains, autonomous systems, or areas. In hierarchical systems, some routers in a domain can communicate with routers in other domains, while others can only communicate with routers within their domain. In very large networks, additional hierarchical levels may exist. Routers at the highest hierarchical level form the routing backbone.

The primary advantage of hierarchical routing is that it mimics the organization of most companies and therefore supports their traffic patterns very well. Most network communication occurs within small company groups (domains). Intra-domain routers only need to know about other routers within their domain, so their routing algorithms can be simplified. Depending on the routing algorithm being used, routing update traffic can be reduced accordingly.

2.4.3 Link State or Distance Vector

Link state algorithms flood routing information to all nodes in the internetwork. However, each router sends only that portion of the routing table that describes the state of its own links. Distance vector algorithms (also known as Bellman-Ford algorithms) call for each router to send all or some portion of its routing table, but only to its neighbors. In essence, link state algorithms send small updates everywhere, while distance vector algorithms send larger updates only to neighboring routers.

Because they converge more quickly, link state algorithms are somewhat less prone to routing loops than distance vector algorithms. On the other hand, link state algorithms require more CPU power and memory than distance vector algorithms. Link state algorithms can therefore be more expensive to implement and support. Despite their differences, both algorithm types perform well in most circumstances.

2.4.4 Other classifications

Global or Local

Global: graph of entire network (routers, links).

Local: partial knowledge of remote parts of network.

Centralized or Decentralized

Centralized: one node maintains view, and distributes routes to other nodes.

Decentralized : all nodes maintain view

Intradomain or Interdomain

Intradomain: algorithm works only within domains

Interdomain: algorithm works within and between domains

Single-Path or Multipath

Multipath: support multiple paths to the same destination

Single-path: doesn't support multiple paths to the same destination

Host-Intelligent or Router-Intelligent

2.5 Desirable Properties in Routing Algorithms

Routing algorithms is distinguished according to several properties where the routing algorithms designers must achieve as much as possible of them. They can use a variety of metrics that affect calculation of optimal route. So in this section we explain the following desirable properties:

Optimality: one of the most desired properties that refer to the capability of the routing algorithm to select the best route, which depends on the metrics and metric weightings used to make the calculation. Some of metrics that are used in routing algorithms are hops and delays, but for this research purpose the delay has been chosen.

Simplicity and low overhead: the routing algorithm must be simple as much as possible which means it provides its functionality efficiently, with a minimum of software and utilization overhead. Since the routing algorithm must run on a computer with limited physical resources. So one of the research aims is to offer a Routing Algorithm that reduce the memory space occupied by routing table as possible, and decrease CPU time needed for routing process, without giving up reaching destination in shortest path.

Robustness and stability: Routing algorithm must guarantee its work correctly in the face of unusual or unforeseen circumstances, for examples high load conditions and hardware failures.

Rapid convergence: Routing algorithms must have agreement, by all routers, on optimal routes. When one of routes either go down or become available, routers distribute routing update messages through networks, stimulating recalculation of optimal routes and eventually causing all routers to agree on these routes which means Routing algorithms must do converge fast as possible to avoid routing loops or network outages.

Flexibility: Routing algorithms should be quickly and accurately adapt to a variety of network circumstances, which means that they can be programmed to adapt to changes in network bandwidth, router queue size, and network delay ...etc.

2.6 Routing Metrics

A metric is a standard of measurement, which is used by routing algorithms to determine the optimal path to a destination. Routing Algorithms use one or more of the following metrics to evaluate which path will be the best for a packet to travel:

- Path length
- Reliability
- Delay

- Bandwidth
- Load
- Communication cost

Path length: is the sum of the costs associated with each link from source to destination, some routing protocols allowing network administrators to determine the costs to each network link. And in other protocols define hop count to be the path length.

Reliability: the ability of network to repair network link failures more easily and more quickly. And usually the network administrators assign the reliability factors (numeric value) to network links.

Routing delay: refers to the length of time required to move a packet from source to destination through the internetwork. Delay is a common and useful metric, because it is accumulation of several important variables. And the researcher will accept routing delay to be the used metric in this research.

Bandwidth: refers to the available traffic capacity of a link.

Load: refers to the degree to which a network resource, such as a router, is busy.

Communication cost: is a cost of sending packets through specific line from source to destination. May be some lines cost money more than another line.

2.7 Flooding and Hierarchical Routing

In this Section we will explore the advantages and disadvantages of both flooding and Hierarchical Routing, which we will depend on in this research.

Advantages of flooding technique:

Simplicity

Efficient when rate of information transmission is low enough that the overhead of explicit route discovery/maintenance is relatively higher

Potentially higher reliability of data delivery

Packets may be delivered to the destination on multiple paths

Disadvantages of flooding technique:

Potentially, very high overhead

Data packets may be delivered to too many nodes who do not need to receive them

Potentially lower reliability of data delivery

Hard to implement reliable broadcast delivery without significantly increasing overhead

Advantages of hierarchical technique:

Scalable

Efficient for large networks such as the Internet inter/intra-domain.

Saves table size.

Reduced update traffic.

Disadvantages of hierarchical technique:

Does not provide accurate routing state information

Estimating the blocking probability of requested connection is quite difficult and complicated.

2.8 what's next

In the next chapter the researcher will consider both hierarchical and flooding as an entrance to obtain a new enhanced routing algorithm.

Chapter 3

Enhanced Controlled Flooding (ECF) Routing Algorithm

3.1 Problems Overview

The fundamental goal of routing algorithm is to determine a best path from one node (source) to another node (destination) within least cost and time 0000.

Nowadays, the network becomes huge –has a huge number of nodes-, and the router routing tables entries have been increased, which cause an increase need for more memory in routers to hold the routing information, and more CPU time is needed to scan them and more bandwidth is needed to send status reports about them.

Hierarchical Routing Algorithms solve previous problems by divide the nodes into regions, but they paid penalty; and this penalty is in the form of increased path length.

3.2 What we need

Design routing algorithm that achieves one or more of the following desirable properties as explained before:

- Optimality
- Simplicity and low overhead
- Robustness and stability
- Rapid convergence
- Flexibility

Also, the Routing Algorithm that we want must reduce the memory space occupied by routing table as possible, and decrease CPU time needed for routing process, without giving up reaching destination in shortest path.

3.3 Proposed Solution

Enhanced Controlled Flooding (ECF), the algorithm we propose in this section, which aims to obtain the benefits from both flooding and dividing networks to many regions like hierarchical technique.

ECF consists of two parts, first part responsible for filling in and updating the routing tables, Second part responsible for choose the preferred control node to send packets through it.

ECF divides networks to regions; each region has two kinds of nodes:

Control Node: The node (router) that connects one region with others. Also it differ here from hierarchical technique that this table includes all routes to all nodes in the network.

Ordinary Node: this node table includes only the routes to all nodes belong to the same region which this node belong to. Also it differ here from hierarchical technique that this table doesn't include any routes to any regions.

Figure (3.1) shows network divided into regions, region A has two control nodes, and region B has three control nodes.

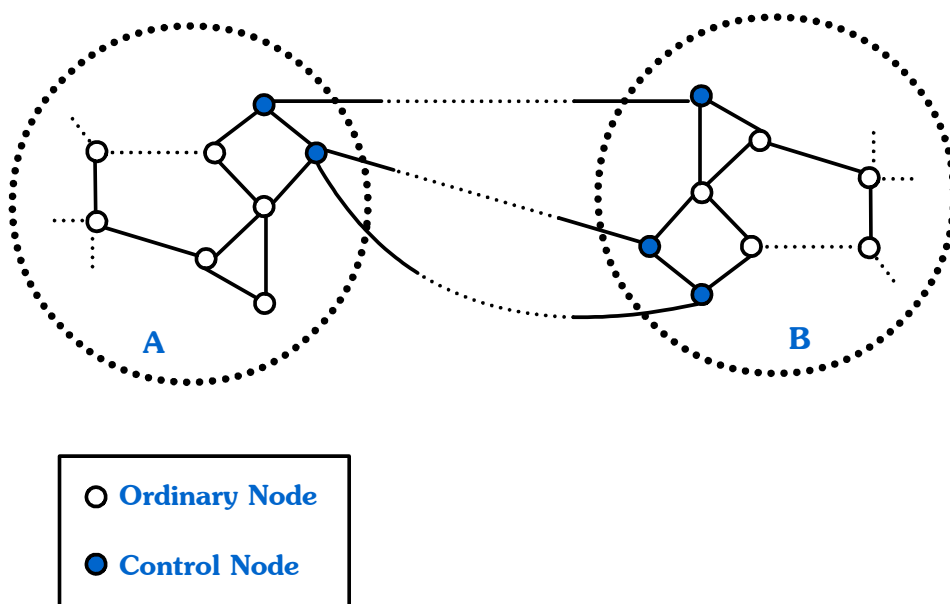


Figure 3.1: Network was divided into region.

ECF uses selective flooding to distribute routing information updates quickly; flooding is the forwarding by a router of a packet from any node to every other node attached to the router except the node from which the packet arrived.

In this section we will discuss the type of packet that will travel in network in our proposed solution, after that we will show the routing table used to save the routing information. Finally we will explain the ECF algorithm parts.

3.3.1 Packets:

In our proposed solution, the routers work with three types of packet: Flooding Packet, Request Packet and Reply Packet. As shown in figure (3.2).

ECF uses the flooding Packet to announce to others that “I Am Here”, and uses others Packet types in ordinary node to determine which Control node it will use to send through it.

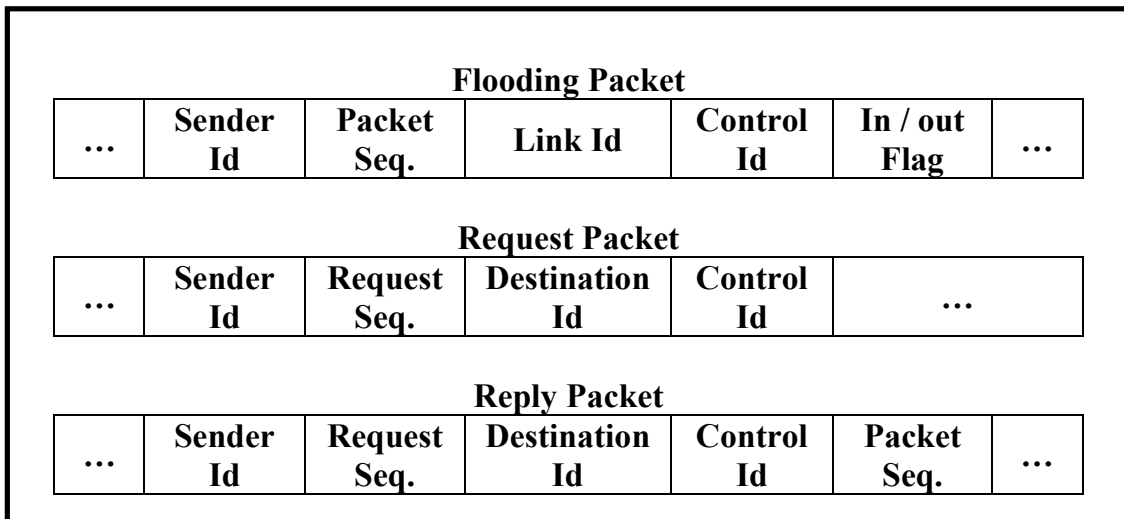


Figure 3.2: Packets used in ECF Algorithm

3.3.2 Routing Table

Routing table is a data structure that is used by a router to hold all information needed to be used in routing processes, in our study we use two different routing tables, because we have two different types of node, first routing table resides in control node, and another one resides in ordinary node, see figure (3.3).

Routing table in ordinary node has one extra field (control node), this field determines if the destination node is control node or not.

.....	Destination Id	Packet Seq.	Control Node	Link Id
.
.
.
	A3	105	1	A3	
	A4	103	0	A3	
	A5	109	0	A4	
.
.
.

Figure 3.3: routing table in ordinary node

3.3.3 Part I (Flooding Receive Part)

ECF Part I (Flooding Receive Part) responsible for filling in and updating the routing tables.

When an ordinary node receives a flooding packet, it examines the inner / outer flag. If this flag value equal (1), then the flooding packet comes from out region, and the node will forward the flooding packet. Otherwise, the flooding packet

comes from same region; the node will look in its routing table to see if the received packet sequence number greater than an entry exists for the same destination node, then the node will update its routing table according to the information carried by the incoming flooding packet and forwards it. Otherwise, the node discards the received packet, because it carries old flooding information.

When a control node receives a flooding packet, it examines the packet sequence number, if the received packet sequence number greater than an entry exists for the same destination node in routing table, then the node will update its routing table according to the information carried by the incoming flooding packet and forwards it. Otherwise, the node discards the received packet, because it carries old flooding information. See Figure (3.4) that shows the ECF Part I.

3.3.4 Part II (Sending Part in Ordinary Node)

Second part of ECF is responsible for choose the preferred control node to send packets through it. This part acts only in ordinary node, and the control node doesn't need this part, because its routing table has all route information to all nodes in the network.

When an ordinary node needs to send information to other node that is reside in different region, the ordinary node send a request packet to collect information about the best path that each control node offered, after that an ordinary node decide which control node that will be used. According to the following steps:

An ordinary node sends request packet to all control nodes in the same region with this information (sender id, request seq., destination id, and control id).

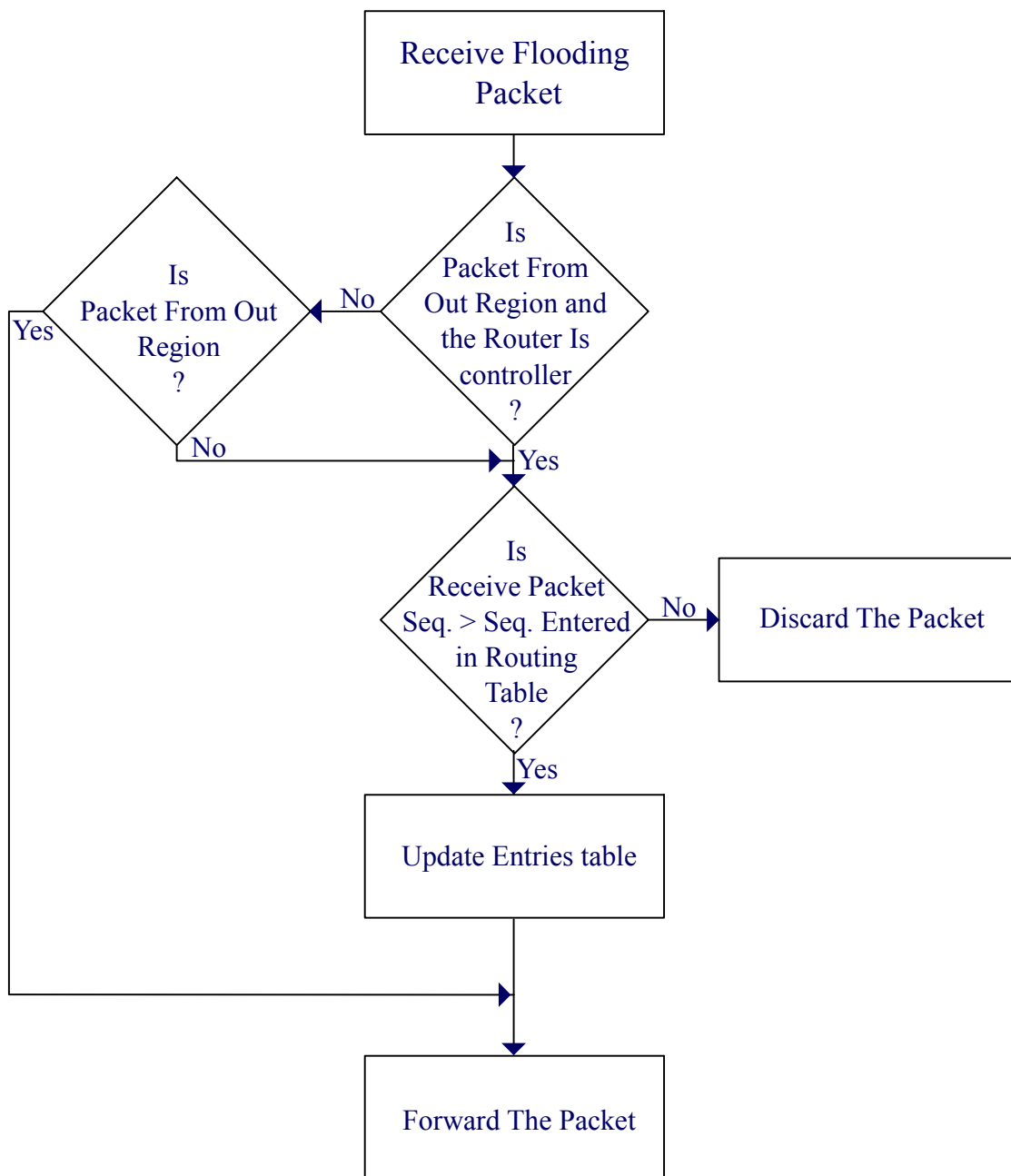
Each control node sends a reply packet to the ordinary node that initiate a request to inform it which route the control node propose including the following reply packet information (control id, packet seq.).

An ordinary node decides which route –control node- is preferred to send through it, using the following criteria:

If controller nodes in all received replied packets are same, then packets will go through this controller node. else,

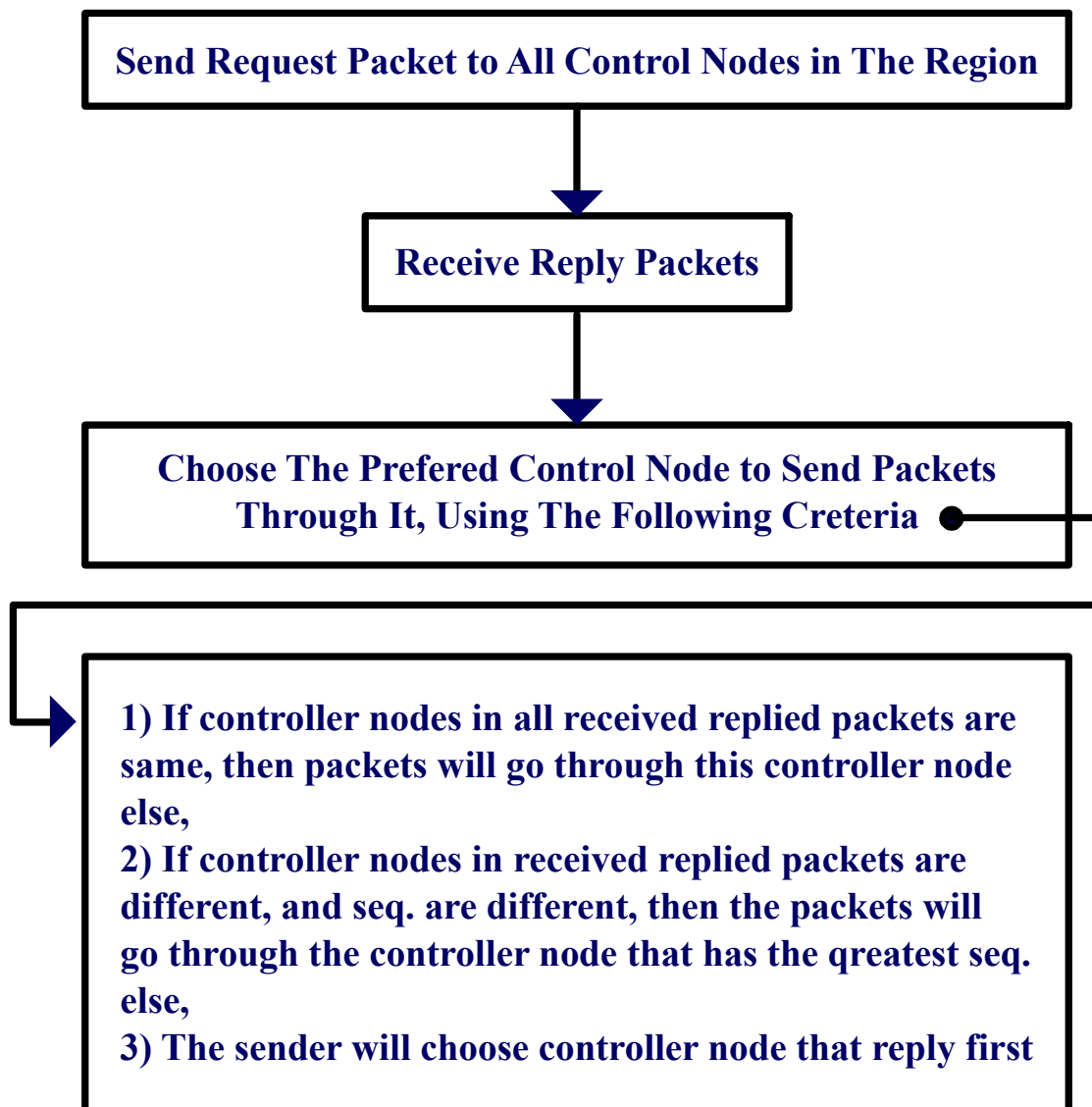
If controller nodes in received replied packets are different, and sequence numbers are different, then the packets will go through the controller node that has the greatest sequence number. else,

The sender will choose controller node that reply first



(ECF) Flooding Receive Part

Figure 3.4: ECF Part I, Flooding Receive Part



(ECF) Sending Part in Ordinary Nodes

Figure 3.5: ECF Part II, Sending Part in Ordinary Node

Chapter 4

Conclusion and Result

In this research, we proposed the Enhanced Controlled Flooding (ECF) routing algorithm to reduce the routing table size, and find the least delay path between two nodes reside in different regions.

The researcher proposed solution was depended on getting most of the advantages form both flooding and hierarchical routing techniques. The researcher classified network nodes (routers) into two different kinds , the first one is an ordinary node and the second is the control node which he use to hold all routing information about all nodes in all regions. After that we proposed Enhanced Controlled Flooding (ECF) routing algorithm which consists of two parts, the first part deals with the all node kinds, and is responsible for filling in and updating the routing tables. The second part deals with ordinary nodes, and is responsible for selecting the preferred control node to send packets through it.

We find out through the examined examples –animation demo- that this proposed solution solves one of the hierarchical routing algorithms disadvantages which is founding the least delay time between two nodes in different regions.

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