XCAST BASED ROUTING PROTOCOL FOR PUSH TO TALK APPLICATION IN MOBILE AD HOC NETWORKS

by

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LIST OF ABBREVIATION

AF	Assured forwarding
ALM	Application Layer Multicast
AMRIS	Ad Hoc Multicasting Routing protocol utilizing Increasing ID NumberS
AMRoute	Ad Hoc Multicasting Routing protocol
AoDV	Ad-hoc on Demand Distance Vector
ASM	Any Source-based Multicast
BA	Behavior Aggregate
BB	Bandwidth Broker
BP	Branch Point
BCast	Branching Cast Protocol
CBR	Constant Bit Rate
CBT	Core Based Tree
CCBR	Customized CBR
CDMA	Code Division Multiple Access
CNetwork	Customized Network Layer
CUDP	Customized UDP Layer

Diffserv	Differential Services
DF	Do not Fragment
DMC	Dual Mode Coding
DR	Designated Router
DSCP	Differential Source Code Point
DSR	Dynamic Source Routing
DVMRP	Distance Vector Multicast Routing Protocol
ECN	Explicit Congestion Notification
EF	Expedited Forwarding
ERM	Explicit Route Multicast Protocol
FEC	Forwarding Equivalence Classes
FIB	Forwarding Information Base
GH	Group Head
GloMoSim	Global Mobile information system Simulator
GR	Group Reliability
GSM	Global System for Mobile communication
GXCAST	Generalized Explicit Multicast Routing Protocol
HBH	Hop-By-Hop Multicast Routing Protocol
IEEE	Institute of Electrical and Electronic Engineers
IETF	Internet Engineering Task Force
IGMP	Intent Group Management Protocol
IMcast	Implicit Multicast Routing Protocol

IMS	Instant Messaging Services
IMs	IP Multimedia subsystem
Intserv	Integrated Services
IP	Internet Protocol
IPDV	IP Packet Delay variation
IPER	IP Packet Error Ratio
IPLR	IP Packet Loss Ratio
IPTD	IP Packet Transfer Delay
ITU	International Telecommunication Union
LMR	Land Mobile Radio
LCA	Two Hop Linked-Cluster Algorithm
MAAA	Multicast Address Allocation Architecture
MANET	Mobile Ad hoc Networks
MAODV	Multicast ad hoc ON-Demand Distance Vector
MCT	Multicast Control Table
MDTP	Multicast Datagram Transfer Protocol
MFT	Multicast Forwarding Table
MMUSIC	Multi-party Multimedia Session Control
MLDv2	Multicast Listener Discovery version 2
MN	Mobile Node
MNCoA	Mobile Node Core Address
MNHOA	Mobile Node Home Address

MPLS	Multi-protocol Label Switching
MSC	Multicast for Small Conference Protocol
MTU	Maximum Transmission Unit
M2X	Multicast to XCAST
NA	Network Administrator
NBT	Non-Ordered Block transfer
OMA	Open Mobile Alliance
OLSR	Optimized link State Routing
PERL	Practical Extraction and Reporting Language
PGMA	Proposed Group Management Algorithm
PHP	Per-Hop-Behavior
PoC	Push-to-talk over Cellular
PTT	Push –To-Talk
P-XCAST	Priority XCAST Based Routing Protocol
QoS	Quality of Service
RFC	Request For Comment
RPB	Reverse Path Broadcasting
RReq	Registration Request
RRep	Registration Reply
RREQ	Route REQuest
RREP	Route REPly
RERR	Route ERORR

RTP	Real-Time Transfer Protocol
RTCP	Real Time Control Protocol
RU	Registration Update
RUNITE	Recursive Unicast Routing Protocol
SBT	Source-based multicast routing protocol
SEM	Simple Explicit Multicast protocol
SIM	Sender Initiated Multicast Protocol
SIP	Session Initiation Protocol
SPT	Shortest Path Tree
TDM	Time Division Multiplex
ToS	Type of Service
TRPB	Truncated Reverse Path Broadcasting
UA	User Agent
UDP	User Datagram Protocol
USM	University Sains Malaysia
VoIP	Voice over IP
XCAST	Explicit Multicast
X2U	XCAST to Unicast
XCAST+	Explicit Multicast Extension
WRep	Withdrawal Reply
WReq	Withdrawal Request

PROTOKOL PENGHALAAN BERASASKAN XCAST UNTUK APLIKASI TEKAN UNTUK BERCAKAP DALAM RANGKAIAN AD HOC MUDAH ALIH

ABSTRAK

Rangkaian ad hoc tanpa wayar merupakan suatu jenis rangkaian tanpa wayar yang mudah dijana tanpa memerlukan infrastruktur atau pengurusan rangkaian. Ianya diolah dan ditadbir ke dalam suatu topologi rangkaian yang bersifat sementara dan dinamik. Walau bagaimanapun, rangkaian ad hoc tanpa wayar ini berhadapan dengan beberapa kekangan yang berkaitan dengan kekurangan aras jalur lebar. Pertumbuhan pesat perkhidmatan subsistem multimedia IP baru (IMs) seperti aplikasi Tekan-Untuk-Bercakap (Push To Talk, PTT) melibatkan penggunaan aras jalur lebar yang tinggi. Keadaan ini menyebabkan penurunan prestasi QoS dalam rangkaian ad hoc tanpa wayar. Berdasarkan kepada thesis ini, adalah dicadangkan supaya Protokol *Priority XCAST based routing (P-XCAST)* digunakan untuk mengurangkan penggunaan aras jalur lebar. P-XCAST digunakan apabila diperlukan dan ianya merupakan mekanisma balasan untuk setiap destinasi dalam lapisan P-XCAST. Untuk membina rangkaian topologi ini dan mengisi jadual untuk kesemua nod, maklumat dalam jadual tersebut digunakan untuk mengklasifikasikan senarai destinasi XCAST mengikut persamaan untuk hop yang seterusnya. Seterusnya, P-XCAST akan bersatu dengan algoritma Pengurusan Kumpulan yang dicadangkan dengan tujuan untuk mengklasifikasikan nod kepada dua jenis; ketua kumpulan dan ahli. Protokol yang dicadangkan diuji dengan rangkaian simulasi GloMoSim dalam beberapa scenario yang berbeza dengan tujuan untuk mengkaji prestasi kualiti perkhidmatan rangkaian metrik. Prestasi P-XCAST adalah 20% lebih baik

berbanding dengan protokol penghalaan lain yang telah diuji. Oleh itu, P-XCAST boleh diaplikasikan dalam beberapa senario berlainan; static atau dinamik. Sebagai tambahan, throughput dan kelewatan pemprosesan dan purata adalah dikira menggunakan model rangkaian beratur; sebagai model ini adalah sesuai untuk menilai IEEE 802,11 MAC yang digunakan untuk aplikasi tekan untuk bercakap. Keputusan analisis untuk throughput link dan kelewatan purata telah digunakan untuk mengesahkan keputusan simulasi.

XCAST BASED ROUTING PROTOCOL FOR PUSH TO TALK APPLICATION IN MOBILE AD HOC NETWORKS

ABSTRACT

Mobile ad-hoc networks comprise a type of wireless network that can be easily created without the need for network infrastructure or administration. These networks are organized and administered into temporary and dynamic network topologies. Unfortunately, mobile ad-hoc networks suffer from some limitations related to insufficient bandwidth. The proliferation of new IP Multimedia subsystem services (IMs), such as Push-to-talk (PTT) applications consume large amounts of bandwidth, resulting in degraded QoS performance of mobile ad-hoc networks. In this thesis, a Priority XCAST based routing protocol (P-XCAST) is proposed for mobile ad-hoc networks to minimize bandwidth consumption. P-XCAST is based on demand route requests and route reply mechanisms for every destination in the P-XCAST layer. To build the network topology and fill up the route table for nodes, the information in the route table is used to classify the XCAST list of destinations according to similarities on their next hop. Furthermore, P-XCAST is merged with a proposed Group Management algorithm to handle node mobility by classifying nodes into two types: group head and member. The proposed protocol was tested using the GloMoSim network simulator under different network scenarios to investigate Quality of Service (QoS) performance network metrics. P-XCAST performance was better by about 20% than those of other tested routing protocols by supporting of group size up to twenty receivers with an acceptable QoS. Therefore, it can be applied under different network scenarios (static or dynamic). In addition Link throughput and average delay was calculated using queuing network model; as this model is suitable for evaluating the IEEE 802.11 MAC that is used for push to talk

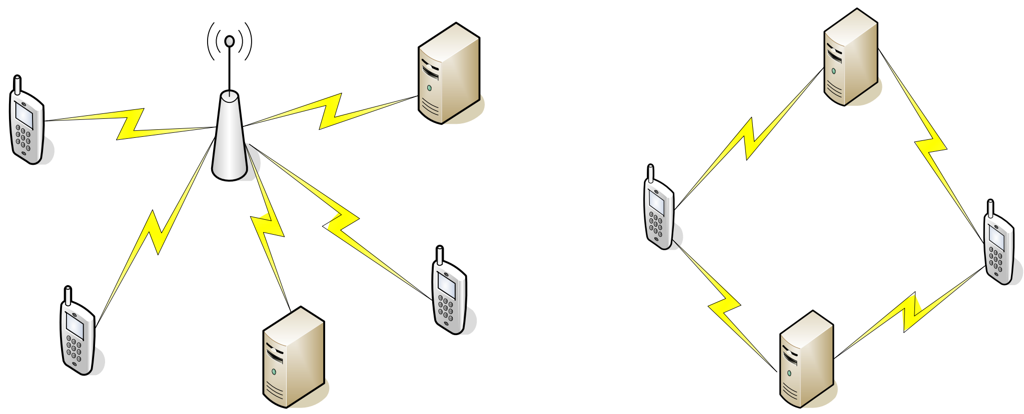
applications. The analytical results for link throughput and average delay were used to validate the simulated results.

CHAPTER 1
INTRODUCTION

In recent years, telecommunications and computer networks have become fast-growing industries whose focus has shifted from voice-centric to data-oriented technology, enabling a seamless communications package. The mobile communication industry first began in the United States in the 1920s using radio telephony. Mobile communications started by using frequency modulation in an analogue system and then evolved into a digital system during its fourth generation (Smith and Collins, 2007).

The use of wireless networks has become a dominant solution for all computer networks. At present, trends indicate the direction of replacing the entire wire infrastructure with wireless networks due to latter's simplicity, flexibility, and ease of use. There are three types of mobile wireless networks (David, 2003): infrastructured, ad-hoc, and hybrid networks combining the features of infrastructured and ad-hoc networks.

Infrastructure networks consist of wireless mobile nodes and one or more bridges connecting the wireless and wired networks. These bridges are called base stations (Figure 1.1). Ad-hoc networks are multi-hops wireless networks without the need for any fixed network infrastructure. Each node can be a source/destination, or a router between the sources and their destinations.



(a) An infrastructure wireless networks (b) Wireless ad-hoc networks

Figure 1.1: Overview of Infrastructure Networks vs. Ad-Hoc Networks.

1.1 Background Information

Push-to-talk over Cellular (PoC) is a kind of real time service using bearer technology. It is important client-server architecture on top of the 3rd generation project and is characterized by the Open Mobile Alliance (OMA) standardization (OMA, 2008). PoC service is a half-duplex form of communication with one or more receivers, similar to a walkie-talkie type operation; in this system, almost half of any conversation is clearly in silence, so any one can talk by simply pushing a button on their handsets. Thus, traditional Time Division Multiplex (TDM)-based circuit switched networks waste channel utility by locating a channel for each call. On the other hand, packet switch networks allow voice communication through User Datagram Protocol (UDP), and the channel is used only during packet transmission. Push-to-talk (PTT) over Internet Protocol (IP) network flows are presented in Figure 1.2, which shows two clients connected across a PTT server (Parthasarathy, 2004).

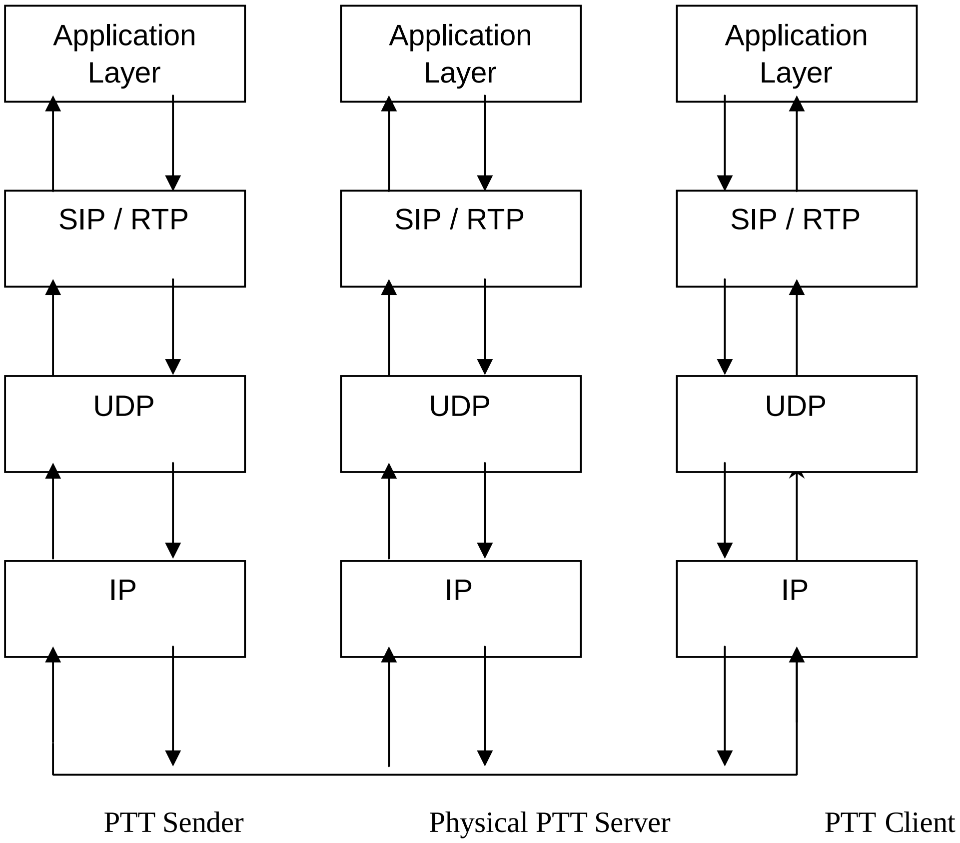


Figure 1.2: Message Flow Scenario across Simple PTT Networks

Meanwhile, Session Initiation Protocol (SIP) is an application layer protocol used for signaling in IP networks developed by the Multi-party Multimedia Session Control (MMUSIC) working group of the IETF (RFC 3261, 2002). SIP is used for session establishment, modification, and session termination (Rosenberg, 2002). There are two types of entities in SIP. SIP User Agents (UAs) comprise the end devices that act as user terminals or automated connection end points; on the other hand, SIP network servers are used by routing all protocols and can have different types of applications (Miladinovic and Stadler, 2002). Real-Time Transfer Protocol (RTP) is the standard for transmitting delay sensitive information across IP networks; it is placed on top of UDP and IP layers (RFC 3350, 2003) although it cannot guarantee QoS or reserve network resources. Real Time Control Protocol (RTCP) allows link monitoring, but most Voice over IP (VoIP) applications offer a continuous stream of RTP/VDP/IP regardless of packet loss or delay in reaching their receivers (Goode, 2002). The Open Mobile Alliance (OMA) standardization specifies certain performance requirements for PoC in order to satisfy the QoS for the users (Ali-Vehmas and Luukkainen, 2006).

1.2 Problem Statement

The starting point of this present study is the commonly accepted view that Mobile Ad-hoc Networks (MANETs) have widespread applications. These applications, such as shared military applications, push-to-talk, and emergency operations, mean that MANETs play a huge role in the development of a nation's technology. Such applications consume a lot of bandwidth and require specific systems to integrate them with other IP-based systems. One unique aspect of PTT compared to other group based communication applications is that, PTT is characterized by many concurrent group sessions with small group sizes.

Due to the limitations of using PTT in IP mobile ad-hoc networks, a solution that satisfies the user requirements of PTT in such environments is needed. Given that there are other challenges in mobile ad-hoc networks that are related to limited bandwidth and node mobility, thus, the proposed solution to implement PTT over mobile ad-hoc networks should enhance the Quality of Service (QoS) to satisfy the user requirements, and reduce the bandwidth consumption through adapting suitable data flow mechanisms, which address the many concurrent small sized group usage scenario.

1.3 Research Motivation

QoS has become a crucial feature in ad-hoc wireless networks due to the growth of multimedia applications consuming large amount of bandwidth. Thus, there have been many proposals to use multicast and add new features to enhance QoS parameters. Multicast is a good solution to support a large number of receivers; however, it has some limitations when used with many small groups (Benslimane et al., 2007). Explicit Multicast (XCAST) is a good data flow mechanism that is used to support large number of small group size. In comparison, there is very limited implementation of XCAST as a data flow mechanism in ad-hoc wireless networks, because it has been originally proposed for wired networks. Hence, adapting XCAST in wireless ad-hoc networks, as well as enabling the development of PTT applications over these networks, is urgently needed. However, MANETs suffer from a group management problem, which must be addressed first in order to support proper operations of PTT services.

1.4 Thesis Objectives

The present thesis objectives are summarized as follows:

- To define a framework for PTT applications over wireless ad-hoc networks (for many concurrent small groups) using suitable data flow mechanisms;
- To enhance existing MANET routing protocols for multiple, concurrent small-sized groups and support PTT applications by addressing group management issues as well as reducing bandwidth utilization; and
- To compare the proposed routing protocol with existing solutions for their ability to support multiple small groups in a MANETs environment.

1.5 Thesis Scope

The objective of this thesis is to propose and design effective data flow mechanisms for PTT applications in mobile ad hoc networks. Since the objectives were focused on defining and evaluating suitable routing and group management protocols and not the physical or data link layer, the following assumptions were made to simplify the analysis and evaluation process: 1) communication channels are error free; 2) nodes have unlimited energy source for the duration of the simulation; and 3) nodes move in an unobstructed open area in a random manner.

1.6 Thesis Organization

The rest of this present thesis is organized as follows: **Chapter 2** presents the background on Mobile ad-hoc network algorithms, multicast for small group algorithms and typical multicast algorithm, QoS approaches, and PTT applications. In addition, this chapter discusses the QoS proposed trends over wireless ad hoc networks. **Chapter 3** defines the proposed framework for PTT applications in mobile ad-hoc networks, the realization of system architecture for PTT over MANETs, group management, and P-XCAST as a data flow mechanism. **Chapter 4** describes simulation environments, network scenarios, theoretical calculations, and the QoS performance metric used in this work. **Chapter 5** describes simulation results and presents the analysis and validation. Finally, **Chapter 6** provides the conclusion and directions for future research work.

CHAPTER 2

LITERATURE REVIEW

2.1 Push-To-Talk Application

PTT is “a walkie-talkie-type,” half-duplex, near real time voice service, which can be viewed as an instant messaging service enhanced with voice functionality. It provides rapid access and two-way communication between two or more parties. Land Mobile Radio (LMR) networks have long supported PTT voice capabilities through the implementation of circuit-switching technologies in the network backbone (Figure 2.1) (Anh et al., 2006). PTT has its roots in military radios. During the last 60 years, it has been the most widely used example of two-way or multiparty radio communication.

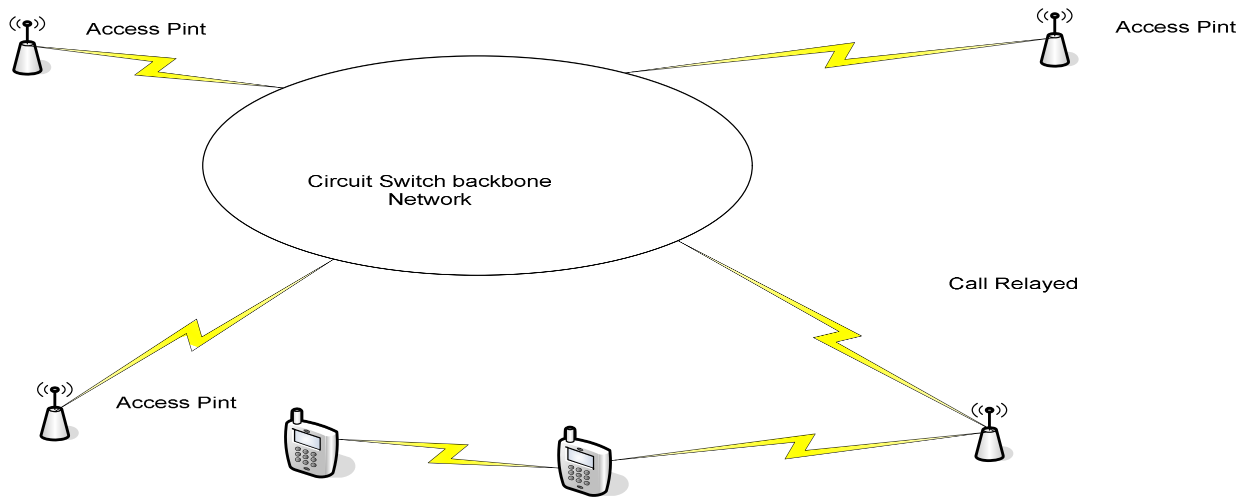


Figure 2.1: Push-to-talk in LMR Networks

The earliest transmitter circuit with a switch appeared in an article published in 1920 (Dasilva et al., 2006). In this system, the operator uses the switch to turn on the transmitter whenever he/she wants to talk. The earliest mobile telephone systems in the 1940s, called radio telephones, also used PTT. Fast forward to autumn of 2003, the consortium of Ericsson, Motorola, and Nokia submitted their jointly defined PoC specification to the OMA; the goal of this submitted proposal was to facilitate interoperability between PTT products and vendors. At present, PoC services offer four different communication modes (Kim et al., 2005). These are listed below.

- *Instant personal Talk*- Here, two users have a private conversation without the understanding of a call setup. User A chooses user B from the address book and presses the talk button. Within two seconds, a start-to-talk indication is received and user A can talk. User A then releases the button after he finishes, giving user B the chance to reply and so on.
- *Ad-hoc Instant Group Talk*- User A dynamically chooses multiple users from his address book before the specific instance that he presses the talk button.
- *Instant Group Talk*- User A chooses group names. The PoC system resolves the group name into a list of group members, after which each member is invited to the group conversation.
- *Chat Group Talk*- A dial-in approach mode is utilized. Each user who wants to participate in a particular chat group talk must actively join by dialing in.

PTT calls exemplify a one-way communication system; while one person speaks, the other is listening. The opportunity to speak is granted by pressing the PTT key on a first come, first served basis. PTT calls are usually connected without requiring the recipients to reply. Alternatively, users can select to receive the PTT calls only after they accept an invitation. If more privacy is needed they can listen to calls through an earphone or headset. The size of PTT groups is normally small of not more than fifty receivers as it is described by the architecture and protocol of a robust distributed PTT service for wireless mesh networks (Amir et al., 2010). PTT has its root in military radio, in addition to the use off PTT in private networks.

2.1.1 Push-To-Talk Features

PTT provides a walkie-talkie type of service to the user, which differentiates it from a normal voice call (Griffin, 2004). A list of comparison is presented below.

- It allows for one-to-one or one-to-many dialogue communication. However, only one person can talk at a time by pressing the talk button.
- It has address and group management function, as it allows multiple people to join in one single communication session.
- It features near instant call setup time.
- Call hold times are shorter than normal conversation style because of the half-duplex operation.
- It guarantees presence information. Users can see who else is logged on, so it is suitable for use in closed loop conference.
- The cost is typically priced below normal mobile phone call charges.
- It facilitates a wide range of conversation styles; here, participants use cellular radios for focused conversation, burst conversation, and intermittent conversation, fluidly moving among these different styles without explicit negotiation (Woodruff and Aoki, 2003).
- It can be integrated with other value-added services and uses existing mobile phone infrastructures, such as Code Division Multiple Access (CDMA) or Global System for Mobile (GSM) communication (Wang and Hou, 2000).
- It results in reduced interaction commitment, in which participants consider the reduced commitment of cellular radio to be an advantage over other media such as the telephone. In addition, opening and closing the interaction are also reduced compared with other media, such as telephone full duplex conversation (Woodruff and Aoki, 2003).
- It demonstrates location based services that are based on IP Multimedia subsystem (IMs) (Mosmonder et al., 2006).

2.1.2 Push-To-Talk Solutions

PTT can be viewed as an Instant Messaging Service (IMS) enhanced with voice functionality. PTT and IMs are highly complementary services. For example, IMs can be used when discretion is important, whereas PTT is more useful on the move (Blum and Magedanz, 2005). The PTT products can be categorized as follows:

- Open Mobile Alliance (OMA) PTT over packet switch networks- Here the vendor offerings are based on OMA specifications (Lin-Yi et al., 2006).
- Proprietary PTT solutions over packet switched networks- In this type of product, vendor offerings for packet switched are not based on OMA specifications. Offerings may differ from OMA specifications, such that signaling procedures are defined and different protocols and compression mechanism are used, among others. Many of the vendors in this category state that PoC compliance is a long-term target.
- Proprietary PTT solution over circuit switched networks- This category contains vendor offerings implemented over circuit switch networks with proprietary PTT signaling procedures and system principles. This category differs from the OMA/PoC solutions.

Packet switched solution is clearly cheaper than circuit switched solution in terms of radio network costs (Blum and Magedanz, 2005). Thus, PTT applications are more ideal for implementation over packet switching due to the number of users, which is expected to exceed 340 million by 2009 (Lavi, et al., 2004). The criteria and comparison for evaluating the various solutions for PTT is shown in Table 2.1.

Present functionality and handset support for different solutions are very important parameters. These include the number of available handset models, their design features, and price level. Its low cost, coupled with ease of use, may lead the PTT market beyond individual subscribers. Traditional LMR handsets are more expensive than PPT commercial systems. By virtue of its user-friendly operation and similarity to mobile phones, PTT needs less training and initial investment than LMR, although it requires larger future expenditures for service (Dasilva, 2006).

Table 2.1: Comparison between Push-To-Talk Solutions

Main criteria	**Packet switched network push-to-talk solution**	**Circuit switched network PTT over GSM**
transport latency session initiation latency	3 second 1- 2 second	150 ms 3- 5 second
Voice quality	Fair speech quality	Good speech quality as GSM
Resource utilization	Over 5 times more efficient than PPT over GSM	Efficient
Cost	Save cost by a factor of over 6 compared to PTT over GSM	More expensive

2.2 Wireless Ad-Hoc Routing Protocols

Ad-hoc network is a type of wireless network with no fixed infrastructure or central administration; it consists of several mobile devices spread in a fixed area that establish peer-to-peer communication. MANETs can support multi-hop communication through IP routing (Ahvar and Fathy, 2007). The working group has classified MANET protocols into two classes as listed below.

- Reactive or on-demand protocols- These decrease the amount of overhead by only initiating a request when it is required, thus they are more suitable for static topologies. However, this mechanism creates a setup delay when building new routes (Novatnak et al., 2005).
- Proactive protocols- These periodically broadcast a control information message across the network in order to build or update routing table for every node. Proactive protocols suffer from larger latencies when substantial mobility exists on the networks.

MANETs have a limited bandwidth and battery lifetime (Bartosz et al., 2007). To minimize bandwidth consumption, proper data flow mechanisms and specific routing protocols must be developed. Although ad-hoc networks have been proposed as a wireless network for PTT application, these have some limitations that can be summarized as follows (Roche et al., 2002):

- no fixed infrastructure or central administration as it is a set of different nodes or stations having a wireless LAN cards;
- limited bandwidth requiring the correct utilization of such bandwidth to guarantee the required QoS metric or parameters; and
- limited battery power since every mobile node is powered by batteries that may not recharged or replaced during a session; thus traffic should be routed in such a way that energy consumption is minimized (Li et al., 2007).

Ad-hoc networks have a dynamic change topology, which makes routing extremely challenging in supporting PTT application. At present, there is a challenge to satisfy QoS requirements starting from a high packet delivery ratio, low latency, and low jitter. This can be achieved by using a proper data flow mechanism that can efficiently utilize bandwidth resources, assign data classification, and prioritize the mechanism.

2.2.1 Ad-hoc On-demand Distance Vector Routing Protocol

Ad-hoc On-Demand Distance Vector (AODV) is a reactive routing protocol that does not maintain routing table information. When a node needs to communicate with another, it makes a route request for that node. The requested node then responds by sending a reply message (Perkins and Royer, 1999). AODV is a distance vector routing protocol, which is easy to deploy because it is based on distance vector routing protocol. A buffer is used in AODV for the data packets until the route has been reconstructed. However, buffering affects the distribution of latencies on the network, and can cause low priority packets that have been generated some time ago to compete with higher priority generated at the present time (Layuan et al., 2007).

2.2.2 Dynamic Source Routing Protocol

Dynamic Source Routing (DSR) is a source-based unicast routing protocol, which lacks effective mechanism for expiring stale routes. It is based on a flaw aggravated by aggressive route caching; thus, it has low reliability in of the face of frequent topological changes (Johnson et al., 2007). The main difference between AODV and DSR is that the former is a distance vector routing protocol that only stores the next hop information in its routing table, whereas the latter uses aggressive route caching. In addition, AODV uses periodic a hello-internal message to detect link breaks.

2.2.3 Location-Aided Routing Protocol

Location-Aided Routing (LAR) is a source-initiated on-demand routing protocol. It uses location information to improve the performance of routing protocols for MANETs, as well as to reduce routing overhead **(**Young-Bae and Nitin, 2000)**.** LAR uses expected zone and request zone for route requests. A node forwards a route request only if it belongs to a request zone; thus the request zone should include the expected zone. The probability of finding a path in the initial request zone can be higher by increasing the size of the initial request zone. However, route discovery overhead also increases with the size of the request zone.

2.2.4 Wireless Routing Protocol

Wireless Routing Protocol (WRP) is a table-driven proactive routing protocol. Each node in the network is responsible for keeping four tables: distance table, routing table, link-cost table, and message retransmission list table. Mobile nodes inform each other of link changes through the use of update messages. These update messages containing information about the destination, the distance to the destination and the predecessor of the destination are sent from nodes to their neighbors. The nodes learn of the existence of their neighbors from the receipt of acknowledgements and other messages (Arnon and Gupta, 1999).

2.2.5 Optimized Link State Routing

Optimized link State Routing (OLSR) is a proactive link state routing protocol. Each node periodically broadcasts its routing table to build a global view of network topology. OLSR incurs a large amount of overhead due to the periodic nature of the protocol. This overhead can be controlled by limiting the number of nodes that forward network-wide traffic. This is achieved through the use of multi-point relays (Clausen and Jacquet, 2003)**.** The two primary control messages used by OLSR are the "hello message" and topology control message.

2.2.6 Overcoming QoS Issues in MANET Routing Protocols

Wireless ad-hoc networks can be used in several areas due to their quick and economic deployment. These applications include multimedia, disaster recovery, and military operations, and these have strict requirements for QoS parameters. QoS is a crucial feature for wireless ad-hoc networks due to the growth of multimedia applications that consume a large amount of bandwidth. Given that bandwidth is a scarce resource, there have been many proposals to use it more efficiently (Zhu, et al., 2004). One of these approaches is to develop multicast in wireless ad-hoc networks (Wu and Jia, 2006). There are many protocols that use multicast as a data flow mechanism in wireless ad-hoc networks, such as On-Demand Multicast Routing Protocol (ODMRP), which is mesh based multicast routing protocol (Lee et al., 2002). Multicast ad-hoc on-demand Distance Vector (MAODV) is another wireless routing protocol which is tree-based (Royer, 1999). The second approach is to add new QoS features to AODV (QS-AODV) by modifying the Route Request (RREQ), Route Reply (RREP), and Route ERORR (RERR) to satisfy QoS requirements (Gulier, 2005). The third approach focuses on path selection to satisfy QoS requirements, and path detection to repair broken links (Lynn, 2003).

2.3 Multicast Routing Protocols in Wired Networks

Multicast is a technique developed to transmit packets from one location (sender) to other locations (receivers). The multicast source sends or transmits packets using a group address (Diot et al., 2002) so that only members of the group can receive the data. This differentiates multicast from broadcast, in which the sender floods the network and related or unrelated members can receive the data packets. The membership of a multicast group can be dynamic or static. In a dynamic group, the host may join or leave the multicast group at any time. Member location or the number of members in the group is not determined, and the host has the option to be a member of more than one group at the same time. Multicast is the most powerful technique used in reducing expensive bandwidth consumption. However, it suffers from drawbacks that will be explained in section 2.5. Multicast uses UDP as a transport protocol instead of TCP because the latter uses frequent transmission of acknowledgement packets between the sender (transmitter) and the receivers.

2.3.1 Multicast Forwarding Algorithms

Several multicast algorithms have been developed in recent years. These are described in the proceeding sections below.

2.3.1.1 Flooding

Flooding is the original proposed algorithm, in which all possible receivers are assumed to have the tendency to receive initial traffic. When the router receives a packet, the router checks if it is the first time that particular packet has arrived. Afterwards, the router forwards the packet to all interfaces, except the one from where it came. This is shown in Figure 2.2.

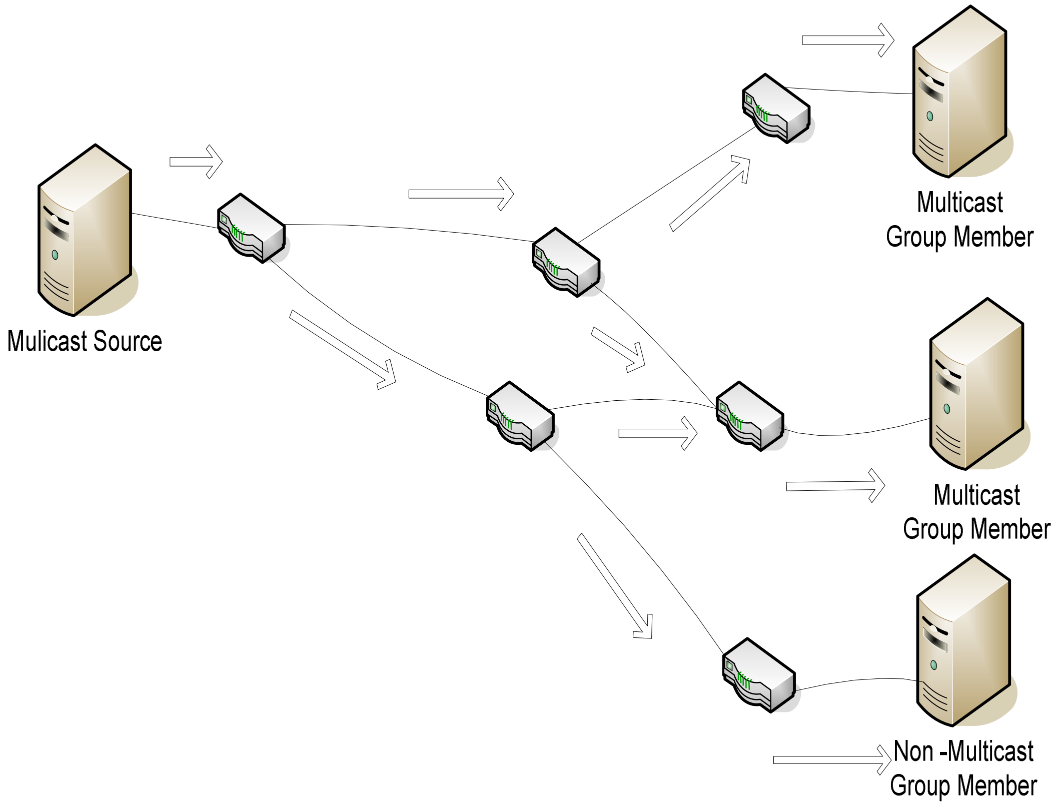


Figure 2.2: Multicast Flooding Mechanism (Diot et al., 2002)

2.3.1.2 Spanning Tree

Spanning tree was developed to reach each member in the group while preventing looping and unnecessary traffic. This is done through Designated Routers (DRs) that construct the spanning tree and connect all the members of an IP multicast group. There is only a single active path between every pair of routers. However, the spanning tree has a disadvantage: it centralizes all traffic on a small set of links. Group membership is also not taken into consideration. To have a good understanding of this algorithm, see Figure 2.3.

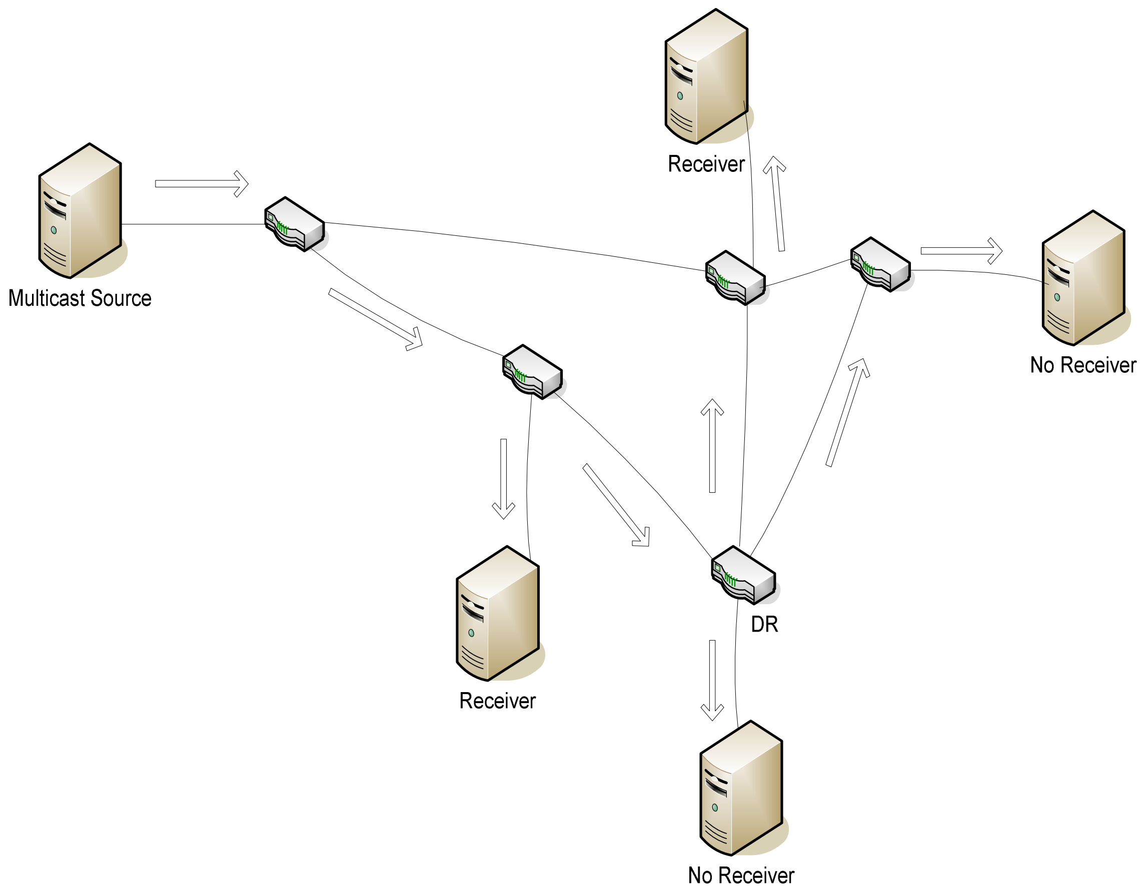


Figure 2.3: Multicast Spanning Tree Mechanism (Diot et al., 2002)

2.3.1.3 Source-based Tree Shortest Path Tree

A tree root at a source node is constructed and connected to every member in the multicast group, and packets are sent via the tree link to all destination nodes. The source of a multicast does not need to know the packet recipients for security purposes. Thus, the multicast routing protocol locates receivers and sets up a multicast tree that links the source to each receiver. There are three schemes to locate and delete changes in the set of receivers: flooding, centralized, and distributed (Ramahol, 2000). Reverse Path Broadcasting (RPB) algorithm keeps the shortest path (best route) between the source and receiver. This is the reason why a delivery path is created for each source, and it is called source tree (Figure 2.4).

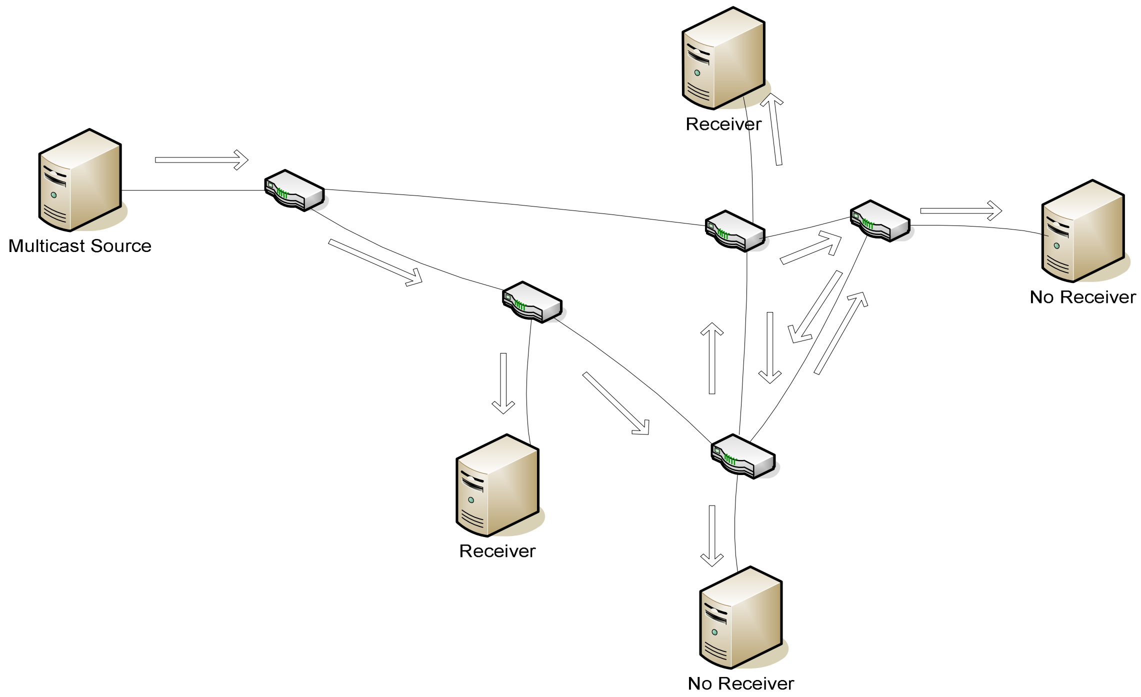


Figure 2.4: Multicast Reverse Path Broadcasting Mechanism (Ramahol, 2000)

With the use of Internet Group Management Protocol (IGMP), this algorithm can be enhanced to Truncated Reverse Path Broadcasting (TRPB) by determining whether or not the group is shown on the routers.

2.3.1.4 Core-based or Shared Tree

A node is selected as the core router, where all packets addressed to a particular group are forwarded as a unicast message (Calberg and Crowcroft, 1997). The core then sends the packets to all outgoing interfaces that are part of the delivery tree. If a host likes to join a group, it sends a join message in the direction of the core (Figure 2.5). A Core-Based Tree (CBT) has many valuable characteristics over source-based multicast routing protocol. This is shown in Table 2.2 .

Table 2.2: Comparisons between Source-based and Core-based Multicast Routing Protocols

Core-based multicast routing protocol (CBT)	Source-based multicast routing protocol (SBT)
It offers more favorable scaling characteristics since Router in CBT does not need to maintain information about each source for each group.	Less scalable
Routers in CBT that are not on multicast tree do not have to be involved in the maintenance activities.	Slow to react in high degree of dynamic routing.
Core management need a mechanism to support encompass selection, distribution, and dynamic placement of core routers (Estrin et al.,1999)	There is no core to manage.
It supports small group.	It supports larger group compared to CBT.

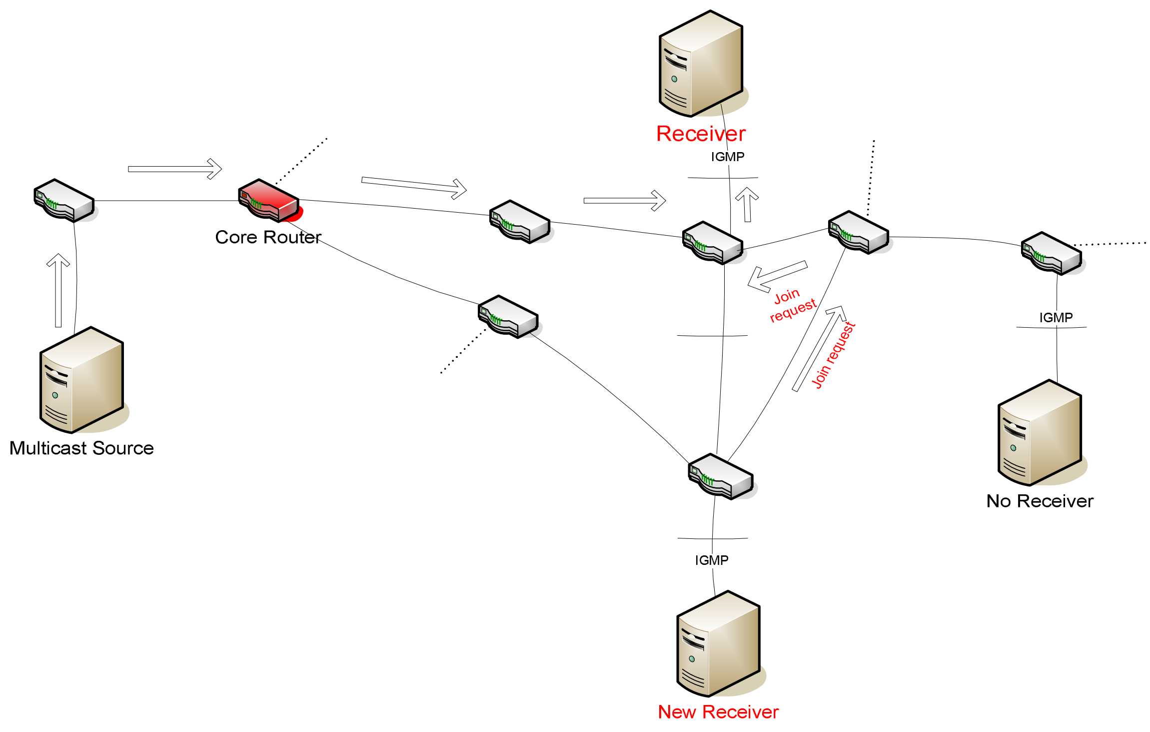


Figure 2.5: Multicast Shared Tree Routing Protocol (Calberg and Crowcroft, 1997)

Multicast or (host) groups have many types (Strigel, 2002) as described below.

- Dense groups have members on most links or subnets in the network, and sparse groups have members on a small number of widely separated links.
- Open groups are those in which the senders need not be a group member, and closed groups in which the source must be a member of that group.
- Permanent groups are those that exist forever or for a long duration, and transient groups are those that exist for a short period of time.
- Static groups have membership which remains constant, and dynamic groups allow members to join or leave the group at any time.

2.3.2 Life Cycle of the Multicast Group

The life cycle of a multicast group can be divided into four steps. The first step is to assign a unique address to the multicast group (i.e., static address for a permanent group and, for security reasons, a dynamic address to a transient group). The second step involved the multicast tree construction with resource reservation to provide QoS guarantee in terms of throughput, end-to-end delay, and delay variation for multimedia applications (Yan et al., 2002). The third step involves data transmission, and the fourth involves a multicast group tear down that occurs when the session lifetime has elapsed.

Tree maintenance includes tree management as well as core and tree migration, because it is important in determining the tree cost and time failure (Strigel, 2002). Figure 2.6 describes the core failure recovery.

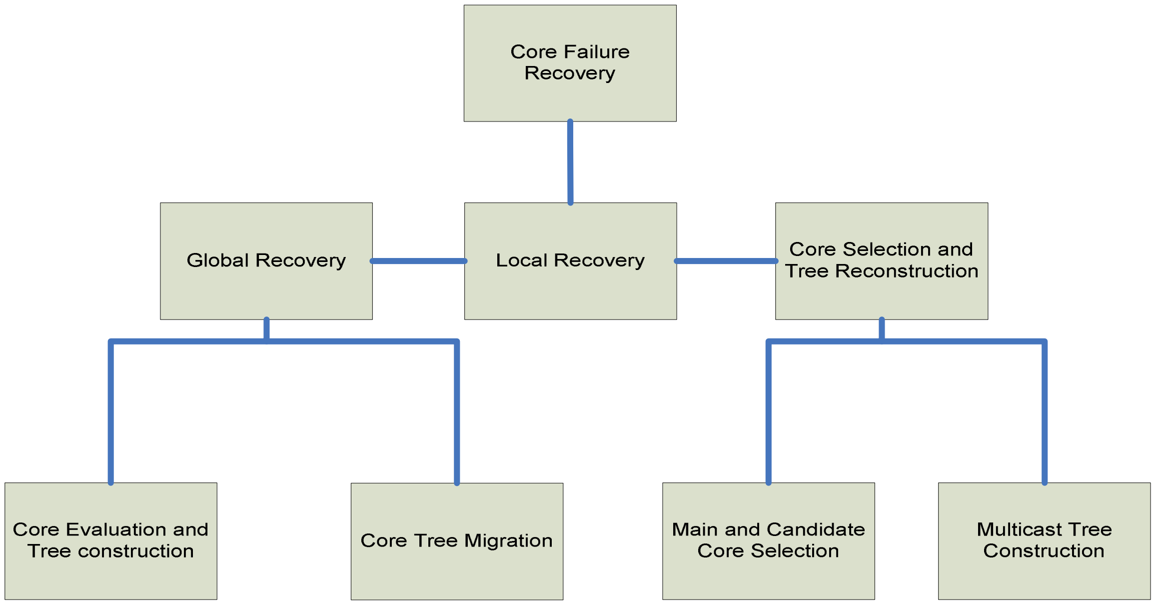


Figure 2.6: Core Failure Recovery for Wired Networks (Strigel, 2002)

2.4 Multicast Routing Protocols in Wireless Ad-Hoc Networks

Multicast routing protocols designed for wired networks are not suitable for wireless ad-hoc networks. This is due to the node's mobility as well as the fact that the transmission medium is not reliable. The multicast routing protocols are also unable to efficiently handle the increased frequency of failures in wireless ad-hoc networks.

2.4.1 Multicast Ad-hoc on-demand Distance Vector

Multicast Ad-hoc on-demand Distance Vector (MAoDV) is a wireless multicast ad-hoc routing protocol associated with AODV. It uses the tree-based approach for multicast routing with a common root shared by all sources and receivers. Each node in the tree keeps a Multicast Route Table (MRT) along with its routing table to support multicast routing, enabling each node to keep track of its upstream and downstream neighbors. Each multicast group has its own sequence number maintained by its group leader. If a node wants to join a group, it sends an RREQ packet with the destination field set as the group ID address. Then, the joining node waits for a reply from the group leader, which then sends an RREP packet (Royer and Toh., 1999). RREP is a control packet containing the following fields: last known group sequence number, address of group leader, and Mgroup Hop initialized to zero.

2.4.2 Multicasting Routing Protocol utilizing Increasing ID number(s)

The Ad-hoc Multicasting Routing Protocol utilizing Increasing ID number(s) (AMRIS) is based on a shared tree structure. It is geared towards long lived multicast session as the route reconstruction is emphasized over route discovery. Each node is assigned an ID number, which increases together with the number of hops. The core node periodically sends a one-hop broadcast containing its ID number as well as those of its parent and children (Mazinan et al., 2008).

2.4.3 Ad-hoc Multicasting Routing Protocol

The Ad-hoc Multicasting Routing Protocol (AMRoute) is another wireless multicast routing protocol based on shared tree (Xie et al., 2002). There are two main phases in AMRoute operations, namely, mesh creation and tree creation. Tree creation is formed by sending a join request message from the core node, and then using expanding ring search to discover the closest member node. The core node identifies the subsets of the links within the mesh to form the shared data delivery tree.

2.4.4 On-Demand Multicast Routing Protocol

On-Demand Multicast Routing Protocol (ODMRP) extends the concept of mesh structure in addition to the forwarding group concept (Lynn, 2003). The forwarding group represents a set of nodes whose function is to forward data depending on the shortest path between any member pairs. Group membership and multicast mesh are established by flooding a JOIN Query from each source using the on-demand approach, leading to a decrease in routing protocol overhead. ODMRP has request and reply phases. Many studies have shown that ODMRP perform better than MAODV, because that latter protocol keeps sending periodic control packets regardless of whether or not there is data transmission (Al-Hunaity et al., 2007).

Table 2.3 presents a comparison between multicast wireless routing protocols. This comparison is based on a primary structure, advertisement, and the reliance of multicast routing protocols on unicast routing protocols for route determination.

Table 2.3: Comparison of Wireless Multicast Routing Protocols (Gretchen H. Lynn, 2003)

	MAODV	**AMRIS**	**AMRoute**	**ODMRP**
Primary Structure	Source tree	Shared tree routed at first sender	Shared tree of virtual links	Mesh of shortest path
Advertisement	Group flooding from the leader	No	Flood from each core	Flood from each sender
Reliance on unicast protocol for routing	On AoDV	No	Any one to make tunnels	No
Members receive redundant data	No	No	No	Yes

2.5 Cost of Multicast

The multicast routing protocol suffers from slow deployment due to many reasons (Diot et al., 2002). These are described in the sections below.

2.5.1 State and Signaling (scalability problem).

Multicast scales well to support a large number of group sizes. However, it cannot scale to support many small groups. This is due to the forwarding state that should be maintained for each group (state per group) in core routers that, in turn, leads to the generation of voluminous multicast forwarding data.

2.5.2 Multicast Address Allocation Architecture

The multicast address allocation problem becomes a serious issue if multicast becomes more popular and widely spread. In this case, routers require more memory for multicast addresses. Fortunately, a transition to IPv6 multicast can help solve the address allocation problems by reducing the chance of address collision to near zero.

2.5.3 Source Discovery

Multicast routing protocols provide a mechanism by which members can connect to even an unknown sender of a certain group. In sparse-mode protocols, the core node should advertise itself in the complete domain, whereas in dense-mode protocols this can be achieved by flooding to all possible receivers.

2.5.4 Group and Network Management

Group management includes group authorization, sender authorization, and receiver authorization. In comparison, network management includes debugging problems that occur within a multicast tree during transmission as well as the monitoring of utilization and operation patterns for the purpose of network planning.

2.5.5 Inter-Domain Protocol

Multicast routing protocols that are dependent on a core needs an inter-domain multicast routing protocol. The traditional multicast model becomes more expensive for its members if the groups are small.

2.5.6 Optimizing Network Bandwidth usage for Group Communications

Several approaches have been proposed to reduce the number of multicast forwarding data state in routers. The first approach is to use a single multicast tree to deliver data for similar receivers (Faloutsos et al., 2001). In the second approach, only the branching routers of a multicast tree have to store forwarding data state (Boudani et al., 2003). The third approach is to move the multicast functionality up to the Application Layer Multicast (ALM). This is a solution that does not take into account the underlying physical network. Data distribution is based on peer-to-peer communications between end systems, and in this scheme, only unicast network primitives are used. ALM protocols construct virtual overlay spanning trees among multicast group members. On the other hand, data distribution along these overlay trees is inefficient, as the same packet may traverse the same physical link several times (Banerjee et al., 2002). Finally, the fourth approach uses small group size multicast routing protocols, such as XCAST.

2.6 Multicast Routing Protocols for Small- to Medium-Sized Groups

Recent developments in the field of communications and the tendency towards real time applications pushed the development of many new technologies that burden the range of available applications. Most of the widely used traditional internet applications, such as web browser and email, operate between one source or sender and one receiver or destination. However, many new applications need one or more sources to synchronously serve a small group size, such as IP telephony, video or audio conferencing, multiplayer games, and PTT applications. Using unicast to support these applications consumes a great amount of bandwidth. Since bandwidth is a scarce