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A performance Evaluation of Broadcast Communication in Wireless Mobile Ad-Hoc Networks

SUBMITTED BY

BENCHETTOUH IKBAL

UNDER THE SUPERVISION

Mr. BENYAHIA MOHAMMED

MEMBER OF JURY

President: ***Mr. OUELD KHAOUA MOHAMED.***

Examiner: ***Mr. KAMECHE ABDELLAH.***

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Dedication

To all my Family.

To all my friends with their help and support.

To everyone who wants to make a positive change in this world.

IKBAL.

Acknowledgements

First, we thank Allah for giving us this opportunity to accomplish this work.

I would like to express my deepest gratitude to my supervisors Dr. Benyahia Mohammed for his support and guidance throughout this research.

Finally, many thanks go to the teachers of Computer science department of Saad Dahlab University.

Abstract.

Wireless mobile ad hoc networks (MANETs) have become of increasing interest in view of their promise to extend connectivity beyond traditional fixed infrastructure networks. Information broadcasting in MANETs is an essential building block for cooperative operations, group discussions, and common announcements (e.g., filling routing tables). The simplest form of broadcast in an ad hoc network is referred to as blind flooding. In this scheme, source nodes broadcast at once packets to all neighbors. Each of these neighbors in turn rebroadcasts the packet exactly once and this process continues until all accessible nodes in the network received the packet. Broadcasting through flooding causes increased messages redundancy, collision and contention, which we call that the broadcast storm problem. Several approaches have been proposed to solve these issues .e.g. Counter-based scheme. This scheme allows nodes to select an appropriate action, either to rebroadcast or to discard receiving messages. The decision is based on the amount of received messages. In this thesis, we compare the performance of the blind-flooding and Counter-based scheme via Simulation using as criteria retransmitting nodes, collision rate, end-to-end delay and reachability especially in the presence of mobility. The simulation scenarios consist of two different settings related to a particular network condition, the impact of network density and the impact of offered load.

Résumé.

Les réseaux mobiles ad hoc sans fil (MANETs) sont devenus de plus en plus intéressants en raison de leur promesse d'étendre la connectivité au-delà des réseaux d'infrastructure fixes traditionnels. La diffusion de l'information dans les MANETs est un élément essentiel des opérations coopératives, des discussions de groupes et des annonces communes (ex., remplir les tableaux de routage). La forme la plus simple de diffusion dans un réseau ad hoc est appelée *Blind-flooding*. Dans ce schéma, les nœuds sources diffusent immédiatement des paquets à tous les voisins. Chacun de ces voisins, à son tour, retransmet le paquet exactement une fois et ce processus se poursuit jusqu'à ce que tous les nœuds accessibles du réseau reçoivent le paquet. La diffusion par *flooding* entraîne une augmentation de la redondance des messages, de la collision et de la contention, ce que nous appelons le problème de la *broadcast storm*. Plusieurs approches ont été proposées pour résoudre ces problèmes, p. ex., l'approche de *Counter-based*. Ce schéma permet aux nœuds de sélectionner une action appropriée, soit pour rediffuser ou pour rejeter les messages reçus. La décision est basée sur le nombre de messages reçus. Dans cette thèse, nous comparons les performances du schéma

Blind-flooding et Counter-based via Simulation en utilisant comme critères les nœuds de retransmission, le taux de collision, le retard de bout en bout et l'accessibilité surtout en présence de mobilité des nœuds. Les scénarios de simulation comprennent deux paramètres différents liés à une condition particulière du réseau, l'impact de la densité du réseau et l'impact de la charge offerte.

ملخص

أصبحت الشبكات اللاسلكية المخصصة المتنقلة أكثر اهتماما نظرا لقدرتها على توسيع نطاق الاتصال بما يتجاوز شبكات الهياكل الأساسية الثابتة التقليدية. ويعد نشر المعلومات في الشبكات اللاسلكية المخصصة يشكل عنصراً أساسياً في العمليات التعاونية ، والنقاشات الجماعية ، والإعلانات المشتركة (على سبيل المثال ، استكمال جداول المسارات). يطلق على أبسط آليات النشر في الشبكات المخصصة اسم مخطط الفياضان الأعمى . في هذا المخطط, يبث المرسل حزم البيانات لجميع جيرانه و يقوم كل من هؤلاء الجيران ، بدوره ، بإعادة إرسال الحزمة مرة واحدة بالضبط ، وتستمر هذه العملية حتى تتلقى جميع العقد التي يمكن الوصول إليها في الشبكة الحزمة. يؤدي نشر المعلومة بالفيضان إلى زيادة تكرار الرسائل ، والتصادم ، والخلاف ، وهو ما نسميه مشكلة عاصفة البث.تم اقتراح عدة طرق لحل هذه المشاكل ، على سبيل المثال ، النهج القائم على العداد. يسمح هذا النظام للعقد بتحديد الإجراء المناسب ، إما لإعادة البث أو رفض الرسائل المستلمة,إذ يعتمد القرار على عدد الرسائل المستلمة. في هذه الأطروحة ، نقارن أداء نظام الفيضان الأعمى والمخطط المعتمد على العداد عبر المحاكاة اعتمادا على معايير تتمثل في عقد إعادة الإرسال, معدل الاصطدام, زمن التأخير من طرف إلى طرف وإمكانية الوصول وذلك بالأخذ بالإعتبار حركة العقد في الشبكة. تتضمن سيناريوهات المحاكاة عاملين مختلفتين يتعلقان بحالة معينة للشبكة، العامل الأول تأثير كثافة الشبكة والآخر تأثير الحمل المقدم.

***Keywords**: MANETs, broadcasting, blind-flooding, counter-based, simulation, mobility , performance.*

CONTENTS

LIST OF FIGURES

List of tables

List of abbreviations

MANETs	Mobile Ad-hoc Networks.
RAD	Random Assessment Delay.
CB	Counter-Based.
BF	Blind-Flooding.
PAN	Personal Area Network.
AODV	Ad Hoc On-Demand Distance Vector.
ZRP	Zone Routing Protocol.
DSR	Dynamic Source Routing .
EAC	Expected Additional Coverage.
C	Threshold.
RF	Random Factor .
NS2	Network Simulator-2.
OTCL	Object-oriented Tool Command Language.
NAM	Network Animator.
RTM	Random Trip Mobility Model .
BIR	Broadcast Injection Rate.

General Introduction

Wireless communication network is currently one of the fastest growing technologies in the world because of the recent advances in wireless technology and mobile computing devices such as laptops, personal digital assistants (PDAs), cell phones etc, it have a number of advantages over their traditional wired counterparts, wireless networks enable connectivity anywhere, anytime, they can be used in areas where there is no wired communication infrastructure or where cabling is difficult to her such as in old buildings. In addition, the installation of a wireless network is cheaper than a cable infrastructure where wireless networks perform an optimum option, especially in less developed global regions. The wireless communications industry has several segments, such as cellular communications, satellite communications, wireless local area networks (WLAN) and global interoperability for microwave access (WiMAX). The de facto adoption of the IEEE 802.11 standard has pushed the development of WLANs and ensured the interoperability of wireless transmission technologies between different providers, which supports the market penetration of the technology. Wireless networks can be classified in two types :

Infrastructure Networks : Infrastructure network consists of a network with fixed and wired gateways. A mobile host communicates with a bridge in the network (called base station) within its communication radius[42]. The mobile unit can move geographically while it is communicating. When it goes out of range of one base station, it connects with new base station and starts communicating through it. This is called handoff. In this approach the base stations are fixed[1].

Infrastructure Less (Ad hoc) Networks : In ad hoc networks all nodes are mobile and can be connected dynamically in an arbitrary manner. As the range of each host's wireless transmission is limited, so to communicate with hosts outside its transmission range, a host needs to enlist the aid of its nearby hosts in forwarding packets to the destination. So all nodes of these networks behave as routers and take part in discovery and maintenance of routes to other nodes in the network[1]. Ad hoc Networks are very useful in emergency search-and rescue operations, meetings or conventions in which persons wish to quickly share information and data[42].

Mobile ad-hoc networks (MANETs) are a type of Ad-hoc network that consist of wireless mobile nodes that cooperatively form a network without specific user administration or configuration, allowing an arbitrary collection to create a network on demand, Scenarios that might benefit from MANET technology include but not limited to, rescue/emergency operations after natural or environmental disasters that destroys existing infrastructure, special operations during law enforcement activities, tactical missions in hostile and/or unknown territories, and commercial/academic gatherings such as conferences, exhibitions and workshops. Currently almost every ad hoc network trusts on IEEE 802.1 1 technology, which denes both physical and MAC layers[31].

In MANETs, broadcasting is a means of diffusing a message from a given source node to all the other nodes in the network. It is a fundamental operation in MANETs and it is a building block for most other network layer protocols, providing important control and route establishment functionality in a number of unicast (one-to-one) routing protocols[31]. For example, many routing protocols such us Dynamic Source Routing (DSR), Ad Hoc On-Demand Distance Vector (AODV) and Zone Routing Protocol (ZRP), use broadcasting to discover new paths, Another application area of broadcasting is in sensor networks for collecting and disseminating critical information, such as temperature, pressure and noise level.

currently, these protocols typically rely on simplistic form of broadcasting called blind flooding, which each node retransmits every unique received packet exactly once. Although blind flooding is extremely simple and easy to implement, it often causes unproductive and harmful bandwidth congestion (called the broadcast storm problem) and it wastes valuable network resources. Recently, a number of researchers have proposed more efficient broadcasting algorithms whose goal is to avoiding the degrading effects of the broadcast storm problem by minimizing the number of retransmissions while attempting to ensure that a broadcast packet is delivered to each node in the network. Counter-based approaches constitute one such a promising solution for broadcasting communication in MANETs.

Related work

In this section we examine related work which directly or indirectly aims at reducing the number of broadcast packets generated by the flooding algorithm.

1- [5] gives a comparative study between broadcasting algorithms, specially simple flooding , the Counter-Based scheme, the Location-Based scheme, Scalable Broadcast

Algorithm and Ad Hoc Broadcast Protocol. Since only one protocol exists in the Simple Flooding category, this protocol is evaluated.

2- [45] and [46] have uses a local topology knowledge for a deterministic studies in order to avoid unnecessary rebroadcasts comparing the added coverage between the rebroadcast of a destination node to that of the source node at each hop, where [46] enhances the algorithm by taking into consideration statistical information about broadcast duplicates, in the other hand, [45] enhances the algorithm by taking into account two-hop coverage.
3- [47] restricting flooding to a subset of nodes (”multipoint relays”) by selecting for each node a minimum number of one-hop neighbors covering all second-hop neighbors.
4- In [48] where the goal of this paper is mainly to provide reliable broadcast delivery. and more recently [49] (with an optimized approach) explore the idea of superimposing a communications graph — a cluster — over the network so that only particular nodes rebroadcast the messages. However, reducing the number of rebroadcast messages, constructing and maintaining the clusters introduce a new source of overhead in a mobile network.
5- Other fields such as percolation theory (Percolation theory studies the flow of fluid in random media and has been generally credited as being introduced in 1957 by Broadbent and Hammersley [50])and random graphs have recently been a source of inspiration for designing solutions within MANETs. Both are based on a probabilistic model and exhibit an interesting phenomenon called phase transition(A phase transition is a phenomenon where a system undergoes a sudden change of state: small changes of a given parameter in the system induces a great shift in the system’s global behavior. This abrupt transition occurs at a specific value pc called the critical point or critical threshold.), where [51] points out that it is occurs in MANETs and may be taken advantage for the elaboration of probabilistic algorithms such as flooding and routing within such networks.
6- [52] studies a gossip-based approach to flooding. Through simulations the authors show that for large networks, a simple gossiping uses up to 35% fewer messages than flooding, and that the performance of AODV routing [53] relying on gossip-based flooding is improved even in small networks of 150 nodes.
7- Zhang and al in [30] proposed a Dynamic probabilistic broadcast scheme as a combination of the probabilistic and counter-based approaches. They have set the

rebroadcast probability of a host according to the host density in its neighborhood area. The scheme is implemented using AODV protocol. Cartigny and Simplot in [54] proposed the Probabilistic scheme as a combination of the advantages of probability-based and distance-based schemes.

8- Khelil et al. in [55] introduce hyper-gossiping, a novel adaptive broadcast algorithm that combines two strategies. Hyper-gossiping uses adaptive gossiping to efficiently distribute messages within single network partitions and implements an efficient heuristic to distribute them across partitions. In [5] Tseng et al., also proposed two adaptive heuristic-based schemes, called adaptive counter-based (ACB) and adaptive location-based (ALB). The authors derived the best appropriate counter threshold and coverage-threshold for ACB and ALB as a function of the number of neighbors. The authors showed that these adaptive schemes outperform the non-adaptive schemes and recommend ACB if location information is unavailable and simplicity is required.

Outline of the Thesis

The rest of the thesis is organised as follows:

Chapter 1 presents brief descriptions of wireless mobile ad-hoc networks (MANETs), characteristics, some of applications on MANETs. Also, presents several routing protocols and broadcasting algorithms.

Chapter 2 talks about blind-flooding broadcasting algorithm and analyzing the main problem known as broadcast storm. Then, presenting the Counter-Based scheme as a solution of broadcast storm with some examples of previous researches which works with Counter-Based scheme.

Chapter 3 talks about simulation frameworks, environments and techniques, and especially descripting NS2 as a chosen simulator for the performance evaluation in the next chapter.

Chapter 4 presents a comparative study and performance analysis of blind-flooding and counter-based schemes using some criteria and a practical mobility model.

Chapter 1: Wireless mobile Ad-Hoc Networks (MANETs)

1.1 DEFINITIONS

The name Ad-Hoc comes from the Latin and means “for this”. As the name suggests, Ad-Hoc Networks are a networks created for a specific purpose. These networks are decentralized, meaning that they do not rely on an already existing infrastructure such as access points or routers.

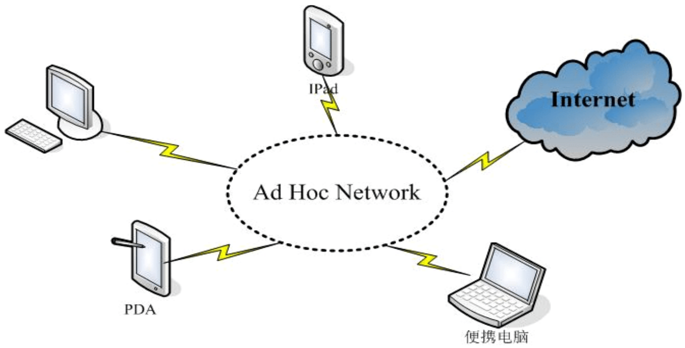

Figure 1-1. Wireless ad-hoc network

In Ad-Hoc Networks each node participates in routing the data to other nodes, managing the routing and to forwarding of packets dynamically[31]. Many techniques are used for these purposes, such as flooding. Typically, every device participating in an ad-hoc network has the same status, and it is free to associate itself with any other ad-hoc network in its link range. There are many kinds of ad-hoc networks with distinct names. For example, the Bluetooth can form an ad-ho c network called Scatternet. A Scatternet is composed of many smaller groups called piconets. Each piconet is formed by a master and a group of up to seven slaves, and to form the larger scatternet, each piconet is linked to another by sharing a common slave no de, or linking one slave node to two different master nodes.

Mobile ad hoc networks (MANETs) have received significant attention in recent years, it’s very superior kind of wireless network environment, it consists of heterogeneous mobile devices like Notebook, cell phone, hand-hold device etc. That communicate with each other, in the absence of a fixed infrastructure. Each device is a mobile node (MN). If two mobile nodes are in each other's radio range, they can send messages and the packets can be relayed by intermediary nodes. MANETs are different from the traditional wireless networks, and as such, are capable of self-configuration, self-healing, self-organization and self-discovering. Research in MANETs was initiated 20 years ago by DARPA for packet radio projects [32].

"Mobile" and "wireless", each of these two words enforces a list of requirements, and the daunting task is to fulfill them to their best. The mobility means that nodes in the networks moves at any time, which implies the short duration of neighbor-hood and topology information received at any moment. In order to handle mobility correctly and efficiently, the information need to be updated regularly. The wireless nature of the medium implies the limited bandwidth capacity, which is further reduced by the high bit error rate in radio transmissions. Being such a precious resource, the bandwidth in a wireless network usually requires prudent consumption.

It is also possible to identify specific sub groups of networks inside a MANET. The Smart Phone Ad-hoc Networks (SPAN), use the existing hardware in commercially available smartphones, such as Bluetooth and Wi-Fi to, for example, create a peer-to-peer (P2P) network without relying on the cellular carrier network, access points or any other traditional network infrastructure. These kind of networks used to rely mostly on the ad-hoc capabilities of the IEEE 802.11 protocol, but the recent *Wi-Fi Direct* opened even more possibilities for these networks. Another common type of MANET are the Vehicular Ad-hoc Networks (VANET), that are used for communication among vehicles and roadside equipment. This kind of networks can help drivers, and prevent collisions, accidents, and other possible hazards [25].

Figure 1-2 shows a typical example of a MANET. Suppose node D is outside the range of node A's transmission range (the dotted circle around node A) and node A is outside the range of node D's transmission range. Therefore, these two nodes cannot directly communicate with each other. If nodes A and D wish to exchange a packet, nodes B and C act as routers and forward the packet on behalf of A and D, since B and C are intermediate nodes that are within the transmission range of A and D.

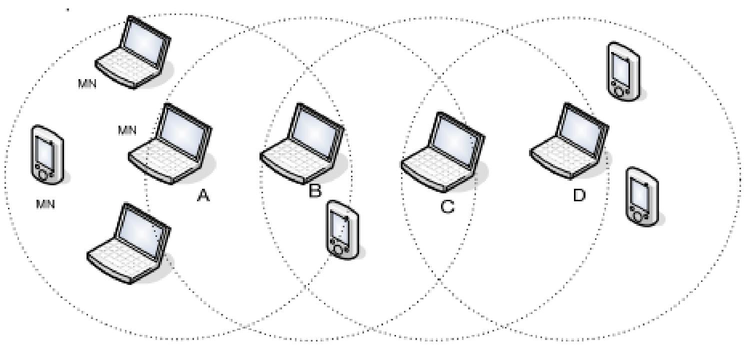

Figure 1-2.scenario for a Mobile Wireless Ad Hoc Network (MANET).

1.2 CHARACTERISTICS OF MANETS

MANETs are self-organizing and adaptive in that the topology of a formed network can change on-the-fly without the intervention of a system administrator.

Although, the fundamental difference between fixed networks and MANETs is that computers in a MANET are mobile, due the mobility of these nodes, there are some characteristics that are only applicable to MANETs[23]. Some of the key characteristics are described below [42][25]:

1.2.1 Dynamic Network Topologies

Nodes are free to move arbitrarily, meaning that the network topology, which is typically multi-hop, may change randomly and rapidly at unpredictable times. Thus an ongoing communication session suffers frequent path breaks. The frequent path breaks in a MANET can be due to the movement of nodes in the network. Also, it can be due to the ability of nodes to leave or join the network at any time. This can be due to individual random mobility, group mobility, motion along pre-planned routes etc.[23] Establishing and maintaining network connectivity in such a mobile environment will require periodic exchange of network information, leading to a possible increase in communication overhead. As a consequence, routing protocols for MANETs must be able to perform efficient and effective mobility management.

1.2.2 Bandwidth constrained links

Wireless links have significantly lower capacity than their hardwired counterparts due to the advent of fiber optic cables. They are also less reliable due to the nature of signal propagation. Due to the frequent changes in the network topology, maintaining consistent topological information at all nodes results in significant communication overhead which, in turn, leads to inefficient utilization of the limited channel bandwidth.

1.2.3 Energy constrained operation

Devices in a mobile network may rely on batteries or other exhaustible means as their power source. For these nodes, the conservation and efficient use of energy may be the most important system design criteria.

1.2.4 Limited Resources

Most ad hoc network nodes such as PDAs, laptops and sensors suffer from constrained resources compared to their wired counterparts. These resources include limited energy, computational power and memory .

1.2.5 Computational power

The computing components used in a mobile node, such as processors, memory and I/O devices, usually have low capacity and limited processing power.

1.3 APPLICATIONS OF MANETS

There are a number of possible application areas for MANETs. These can range from simple commercial applications to complicated high-risk emergency services and battlefield operations [25][42].

Below are some significant examples including emergency and military domains :

1.3.1 Rescue/Emergency operations

Rapid installation of a communication infrastructure during a natural/environmental disaster that demolished the existing communication infrastructure line telephone lines, backbones and access points.

1.3.2 Law enforcement activities

Rapid installation of a communication infrastructure during special operations.

1.3.3 Commercial projects

Simple installation of a communication infrastructure for commercial gatherings such as conferences, exhibitions, workshops and meetings.

1.3.4 Educational classrooms

Simple installation of a communication infrastructure to create an interactive classroom on demand.

1.3.5 Personal Area Network (PAN)

Short-range MANET can simplify the intercommunication between various mobile devices (such as a PDA, a laptop, and a cellular phone).

1.3.6 Battlefield Operations

In future battlefield operations, autonomous agents such as unmanned ground vehicles and unmanned airborne vehicles will be projected to the front line for intelligence, surveillance, enemy antiaircraft suppression, damage assessment and other tactical operations.

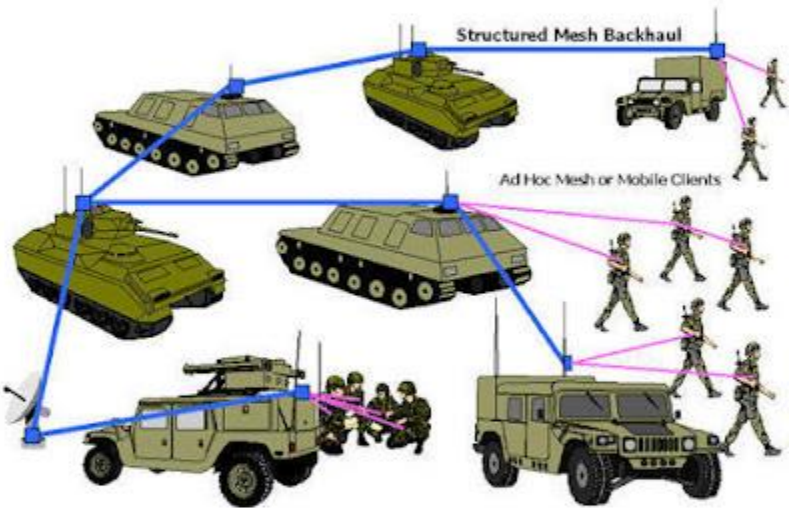

Figure 1-3 Battlefield operations example

1.4 BROADCASTING IN WIRELESS MANETS

Broadcasting is a fundamental operation in MANETs in many applications, e.g., graph-related problems and distributed computing problems, whereby a source node sends the same packet to all the nodes in the network. the problem of sending a message from a source node to all the other nodes of the network, a wireless MANET is a set of nodes communicating with each other via multi-hop wireless links. Each node can directly communicate with only those nodes that are in its communication range. In multi-hop wireless MANETs where all the nodes may not be within the transmission range of the source, intermediate nodes may need to assist in the broadcast operation by retransmitting the packet to other remote nodes in the network. Since the nodes are mobile, the topology of the network is constantly changing.

1.4.1 Broadcasting in Routing

Routing protocols allow for point- to-point communication in ad hoc networks. Routing protocols are responsible for delivering packets between nodes not within the transmission range. This requires the use of cooperative intermediate nodes that are able to act as router s in a distributed manner, thus allowing for data packets to be forwarded toward their destination. In[34] Alagan give a survey paper focuses on the taxonomy related to ad hoc routing techniques and compares the features of routing protocols.

Ad hoc network routing protocols may be classified as proactive or reactive (on-demand) depending on how they determine routes. Broadcasting is utilized in reactive routing for route discovery and in proactive routing for link dissemination[13].

1.4.1.1 Proactive Protocols [2]

• APRL (Any Path Routing without Loops) is described in "Dynamic Neighbor Discovery and Loop-Free, Multi-Hop Routing for Wireless, Mobile Networks".

• CGSR (Cluster-Head Gateway Switch) is described in "Routing in Clustered Multi-hop Mobile Wireless Networks with Fading Channel".

• DSDV (Destination Sequenced Distance-Vector) is described in "Ad-hoc OnDemand Distance Vector Routing".

• FSR (Fisheye State Routing, commonly referred to as Fisheye) is described in "Scalable Routing Strategies for Ad Hoc Wireless Networks" [Iwata99].

• GSR (Global State Routing) is described in "Global State Routing: A New Routing Scheme for Ad-hoc Wireless Networks".

• HSR (Hierarchical State Routing) is described in "Scalable Routing Strategies for Ad Hoc Wireless Networks".

• OLSR (Optimized Link State Routing) is described in "The Optimized Link State Routing Protocol, Evaluation Through Experiments and Simulation", "Optimized Lin1c State Routing Protocol" [Clausen03], and "Optimized Link State Routing Protocol for Ad Hoc Networks"

• STAR (Source-Tree Adaptive Routing) is described in "Transmission-Efficient Routing in Wireless Networks Using Link-State Information".

• WRP (Wireless Routing Protocol) is described in "A Routing Protocol for Packet Radio Networks" and "An Efficient Routing Protocol for Wireless Networks".

1.4.1.2 Reactive Protocols[2]

• ABR (Associativity-Based Routing) is described in "Associativity Based Routing for Ad Hoc Mobile Networks"

• AODV (Ad Hoc On-Demand Distance-Vector Routing) is described in "Evolution and Future Directions of the Ad-hoc On-Demand Distance Vector Routing Protocol", "Ad-hoc On-Demand Distance Vector Routing", "A Quick Guide to AODV Routing", and "AODV Routing Implementation for Scalable Wireless Ad-Hoc Network Simulation (SWANS)".

• DSR (Dynamic Source Routing) is described in "DSR: The Dynamic Source Routing Protocol for Multi-Hop Wireless Ad Hoc Networks".

• FORP (Flow-Oriented Routing Protocol) is described in "IPv6 Flow Handoffin Ad Hoc Wireless Networks Using Mobility Prediction".

• LAR (Location Aided Routing) is described in "Location-Aided Routing (LAR) in Mobile Ad Hoc Networks".

• ODMRP (On-Demand Multicast Routing Protocol) is described in "On-Demand Multicast Routing Protocol in Multi-hop Wireless Mobile Networks" .

• PAOD (Power-Aware On-Demand) is described in "Power-Aware On-Demand Routing Protocol for MANET".

• PLBR (Preferred Link-Based Routing) is described in "A Preferred Link-Based Routing Protocol for Ad Hoc Wireless Networks".

• RDMAR (Relative Distance Micro-discovery Ad-hoc Routing) is described in "RDMAR: A Bandwidth-efficient Routing Protocol for Mobile Ad hoc Networks".
• GRAD (Gradient Routing in Ad-hoc networks) is described in "Gradient Routing in Ad Hoc Networks".

• SSA (Signal-Stability Based Adaptive) is described in "Signal Stability-Based Adaptive Routing (SSA) for Ad Hoc Mobile Networks".

• TORA (Temporarily Ordered Routing Algorithm) is described in "Temporarily Ordered Routing Algorithm" [SECAN-LAB05A] and "Trusted Route Discovery with the TORA Protocol".

1.4.2 Broadcasting Methods

Williams and camp categorized broadcasting protocols into four families [11] [21] :

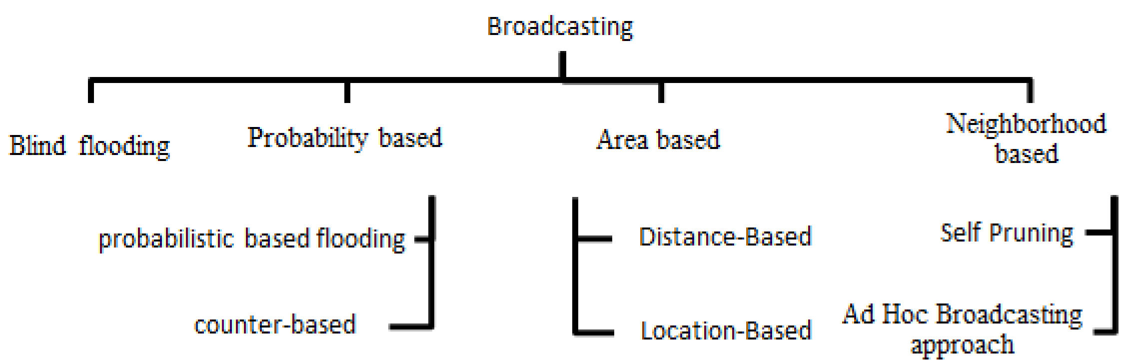

Figure 1-4. Broadcasting methods

A) Blind flooding: requires each node in a MANET to rebroadcast all packets once [12].

B) Probability based: assigns probabilities to each node to rebroadcast depending on the topology of the network.

- ***probabilistic based flooding* :** The Probabilistic scheme from is similar to Flooding, except that nodes only rebroadcast with a predetermined probability. In dense networks multiple nodes share similar transmission coverage. Thus, randomly having some nodes not rebroadcast saves node and network resources without harming delivery effectiveness. In sparse networks, there is much less shared coverage; thus, nodes won't receive all the broadcast packets with the Probabilistic scheme unless the probability parameter is high. When the probability is 100%, this scheme is identical to Flooding.

- ***Counter-Based scheme*****:** Ni et al [19][41] show an inverse relationship between the number of times a packet is received at a node and the probability of that node being able to reach additional area on a rebroadcast. This result is the basis of their Counter-Based scheme. Upon reception of a previously unseen packet, the node initiates a counter with a value of one and sets a RAD (which is randomly chosen between 0 and Tmax seconds). During the RAD, the counter is incremented by one for each redundant packet received. If the counter is less than a threshold value when the RDT expires, the packet is rebroadcast. Otherwise, it is simply dropped. From [19], threshold values above six relate to little additional coverage area being reached.

C) Area based methods: Suppose a node receives a packet from a sender that is located only one meter away. If the receiving node rebroadcasts, the additional area covered by the retransmission is quite low. On the other extreme, if a node is located at the boundary of the sender node's transmission distance, then a rebroadcast would reach significant additional area, 61% to be precise . A node using an Area Based Method can evaluate additional coverage area based on all received redundant transmissions. We note that area based methods only consider the coverage area of a transmission; they don't consider whether nodes exist within that area[21].

- ***Distance-Based scheme*****:** A node using the Distance-Based Scheme compares the distance between itself and each neighbor node that has previously rebroadcast a given packet1. Upon reception of a previously unseen packet, a RAD is initiated and redundant packets are cached. When the RAD expires, all source node locations are examined to see if any node is closer than a threshold distance value. If true, the node doesn't rebroadcast.
- ***Location-Based scheme*****:** The Location-Based scheme [21] uses a more precise estimation of expected additional coverage area in the decision to rebroadcast. In this method, each node must have the means to determine its own location, e.g., a Global Positioning System (GPS). Whenever a node originates or rebroadcasts a packet it adds its own location to the header of the packet. When a node initially receives a packet, it notes the location of the sender and calculates the additional coverage area obtainable were it to rebroadcast. If the additional area is less than a threshold value,

the node will not rebroadcast, and all future receptions of the same packet will be ignored. Otherwise, the node assigns a RAD before delivery. If the node receives a redundant packet during the RDT, it recalculates the additional coverage area and compares that value to the threshold. The area calculation and threshold comparison occur with all redundant broadcasts received until the packet reaches either its scheduled send time or is dropped.

D) Neighborhood based [7] [29]: State on the neighborhood is maintained by neighborhood method, and the information obtained from the neighboring nodes is used for rebroadcast.

- ***Self-pruning* (SP)** [34]: Self Pruning is an effective method in reducing broadcast redundancy. Each node in this approach is required to have knowledge of its neighbors, this knowledge can be achieved by periodic ”Hello” messages. The receiving node will first compare its neighbor lists to that of sender's list, the receiving node will rebroadcast if the additional nodes could be reached, otherwise the receiving node will drop the message. This is the simplest approach in the neighbor knowledge method.

  As it can be seen in Fig.1-5, after receiving a message from node 2, node 1 will rebroadcast the message to node 4 and node 3 as they are its only additional nodes. Note that node 5 also will rebroadcast the same message to node 4 as it is the only additional node. Thus, message redundancy still takes place under SP.

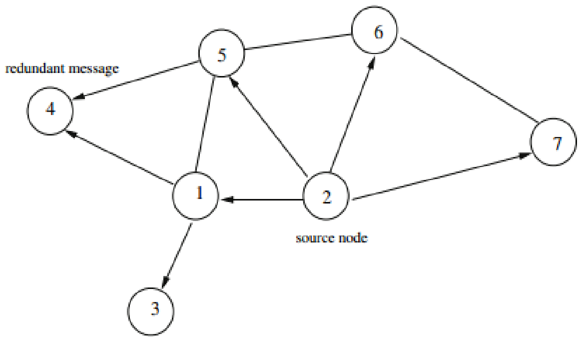

Figure 1-5. Self-Pruning approach

- ***Dominant Pruning*:** Dominant Pruning makes use of the two hop neighbor knowledge via "Hello Packets" sent to obtain the list of two hop neighbors. Here the re broadcasting nodes proactively selects the nodes which will be further re broadcasting the packets from its 1 hop neighbors. Only these selected nodes are allowed to re broadcast.

- ***Multipoint Relaying*:** Multipoint Relaying [43] is similar to Dominant Pruning in that rebroadcasting nodes are explicitly chosen by upstream senders. For example, say Node A is originating a broadcast packet. It has previously selected some, or in certain cases all, of it one hop neighbors to rebroadcast all packets they receive from Node A. The chosen nodes are called Multipoint Relays (MPRs) and they are the only nodes allowed to rebroadcast a packet received from Node A. Each MPR is required to choose a subset of its one hop neighbors to act as MPRs as well. Since a node knows the network topology within a 2-hop radius, it can select 1-hop neighbors as MPRs that most efficiently reach all nodes within the two hop neighborhood. The authors of [43] propose the following algorithm for a node to choose its MPRs:

  1. Find all 2-hop neighbors that can only be reached by one 1- hop neighbor. Assign those 1-hop neighbors as MPRs.

  2. Determine the resultant cover set (i.e., the set of 2-hop neighbors that will receive the packet from the current MPR set).

  3. From the remaining 1-hop neighbors not yet in the MPR set, find the one that would cover the most 2-hop neighbors not in the cover set.

  4. Repeat from step 2 until all 2-hop neighbors are covered. Multipoint Relaying is described in detail as part of the Optimized Link State Routing (OLSR) protocol defined by an Internet draft [4]. In this implementation, “Hello” Packets include fields for a node to list the MPRs it has chosen. Anytime a node receives a “Hello” packet, it checks if it is a MPR for the source of the packet. If so, it must rebroadcast all data packets received from that source. Clearly, the update interval for “Hello” packets must be carefully chosen and, if possible, optimized for network conditions

- ***Ad Hoc Broadcasting approach* [42]:** In this approach, only nodes selected as gateway, nodes and a broadcast message header are allowed to rebroadcast the message. The approach is described as follows:

  1- Locate all two hop neighbors that can only be reached by a one hop neighbor. Select these one hop neighbors as gateways.

2- Calculate the cover set that will receive the message from the current gateway set

3- for the neighbors not yet in the gateway set, find the one that would cover the most two hop neighbors not in the cover set. Set this one hop neighbor as a gateway.

4- Repeat process 2 and 3 until all two hop neighbors are covered.

5- When a node receives a message and is a gateway, this node determines which of its neighbors already received the message in the same transmission.

1.4.3 Comparison of broadcast techniques

Identifying five decisive criteria for success of broadcasting protocols in a wide of network and to collect the performances of the selected protocol, in table 1 we present a comparative study of the previous broadcast protocols using the following criteria:

Efficiency : The efficiency of broadcast protocol is an important factor to present network congestion, especially in dense network, where protocols should be effectively dispose of redundant rebroadcasts, considering that data packets are expected to be bigger than the “hello” message used in routing protocols.

Robustness to mobility: the chosen broadcast protocol should be able to adapt to a high degree of mobility in the network.

Adaptability to network topology: broadcast protocols should be able to adapt to the local topology and its changes and types, dense or sparse, in different regions and times.

Latency: to ensure the quality of packets sended as voice-data, data packets should be transported with minimum delay. Hence, the protocol should seeks to minimize the latency.

Simplicity: the protocol should be simple enough to operate on devices that consume more power for their CPU, memory …

Table 1-1: Performance of MANET broadcast protocols on various dimensions

	Efficiency	Robustness to mobility	Latency	Adaptability to net. Topology	Simplicity
Blind flooding	Highly inefficient	Very good	No	Low	Very simple
Probabilistic based flooding	Moderately efficient	Good	No	Low	Simple
Counter-based	Moderately efficient	Good	Yes	High	Moderate
Dynamic probabilistic	Moderately efficient	Good	No	High	Moderate
Distance based	Efficient	Sufficient	Yes	Moderate	Moderate
Location based	Efficient	Sufficient	Yes	Moderate	Moderate
Self-pruning	Efficient	Sufficient	No	High	Moderate
Multipoint relaying	efficient	Low	No	High	complex
AHBP	Highly efficient	Low	No	High	Complex

Blind flooding is inefficient in dense network whereas almost nodes rebroadcasting all time what causes congestion in network, on the contrary in sparse network.

Probabilistic-based: many research demonstrate that using a fixed probability can reduce successfully redundant rebroadcast with an optimal value for this probability around 0.65, but it is not optimum for all network. In dense network, lesser nodes are required to rebroadcast, and this need a probability lesser than 0.65, while in sparse network more nodes required for rebroadcasting demand a value greater than 0.65.

Counter-Based: simple little bit to adapt automatically to the topology and ensures that lesser nodes rebroadcast in dense areas, while all nodes rebroadcast in sparse network. However, the protocol incurs a latency because of using of the RAD.

Area-based: both (location-based & distance-based) can predict the extra area covered not the number of nodes, and both require certain special features for the mobile devices. Distance-based require detect the signal strength of a communication with high accuracy, while location-based require each node contain a GPS for position detection.

Neighbor-based: the most complex protocols, more "hello" messages required to collect the 2-hope information in every node and choosing of the Multipoint Relays node in Multipoint Relaying protocol, and that product high complexity, but they are efficient to decrease the redundant rebroadcast.

CHAPTER 2: Blind-flooding & Counter-Based

2.1 BLIND FLOODING (BF)

Blind flooding is the simplest form of broadcast in an ad hoc network, where a node transmits a packet, which is received by all neighboring nodes that are within the transmission range [37]. Upon receiving a broadcast packet, each node determines if it has transmitted the packet before. If not, then the packet is retransmitted. This process allows for a broadcast packet to be disseminated throughout the ad-hoc network. Blind flooding terminates when all nodes have received and transmitted the packet being broadcast at least once [29]. As all nodes participate in the broadcast, blind flooding suffers from the Broadcast Storm Problem [38]. The broadcast storm problem states that, in a CSMA/CA network, blind flooding is extremely costly and may result in the following [33] [37]:

2.1.1 Redundant rebroadcasts

Occur when a node decides to rebroadcast a message to its neighbors; however, all neighbors have already received the message. Thus the transmission is redundant and useless.

2.1.2 Contention

After a mobile host broadcasts a message, if many of its neighbors decide to rebroadcast the message, these transmissions (which are all from nearby hosts) may severely contend with each other.

2.1.3 Packet collision

Because of the lack of the back-off mechanism, RTS/CTS dialog, and the absence of CD, collisions are more likely to occur and result in lost or corrupted messages.

Blind flooding causes a high network routing load in the network due to the broadcast storm problem [2], and as a result consumes high energy.

Figure 2-1. Shows redundant broadcast and contention of the broadcast storm problem when performing a blind flood. In Fig. 2-1, node A initiates a broadcast of a message and the message is received by nodes B and C. According to blind flooding, B and C rebroadcast the message if they had not broadcasted it before. Therefore, D will receive the message and also rebroadcast the message if there is no collision. It may cause the following problems[39]:

- Since node D is inside the transmission range of nodes B and C, it will receive two redundant copies of the message from nodes B and C.
- Nodes B and C may contend for the broadcast medium in the shadow area. If there are more nodes in the shadow area, there will be an increase in contention for the broadcast medium.

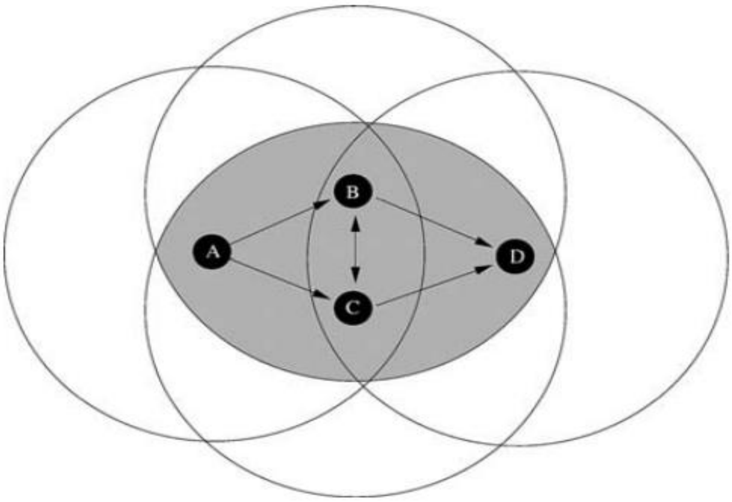

Figure 2-1. Broadcast storm problem

In a MANET of size m where m is number of node, the number of message is of the magnitude (m^2) and is depicted in figure.2-2.

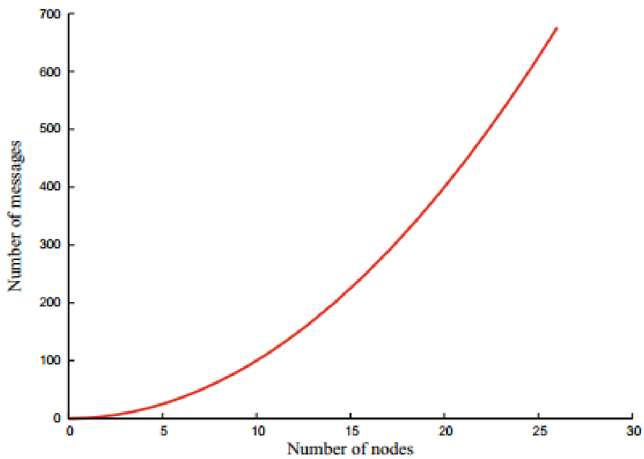

Figure 2-2. O(m^2) number of messages in a simple flooding method

Some analyses provide that rebroadcasts are very costly and should be used with caution, we consider the simple scenario in figure 2-4, where host A sends a broadcast message, and host B decides to rebroadcast the message. Let S_A and S_B denote the circle areas covered by A's and B's transmissions, respectively. The analyses prove that the additional area (the shaded region) that can benefit from B's rebroadcast (denoted as $|S_{B-A}|$), can provide 0–61% additional coverage over that already covered by the previous transmission.

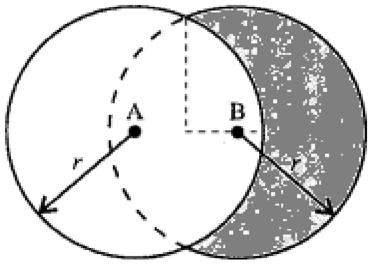

Figure 2-3. Analysis of the extra area that can benefit from a rebroadcast.

We would like to know the benefit of a host rebroadcasting a message after hearing the message **K** times. The result can be easily obtained from simulation by randomly generating **k** hosts in a host X's transmission range and calculating the area covered by X excluding those areas already covered by the other **k** hosts. Denote this value by EAC(**k**) (EAC stands for expected additional coverage). Figure 2-5 shows our simulation result (again by grid estimation). As can be seen, when **k** ≥ 4, the expected additional coverage is below 5%.

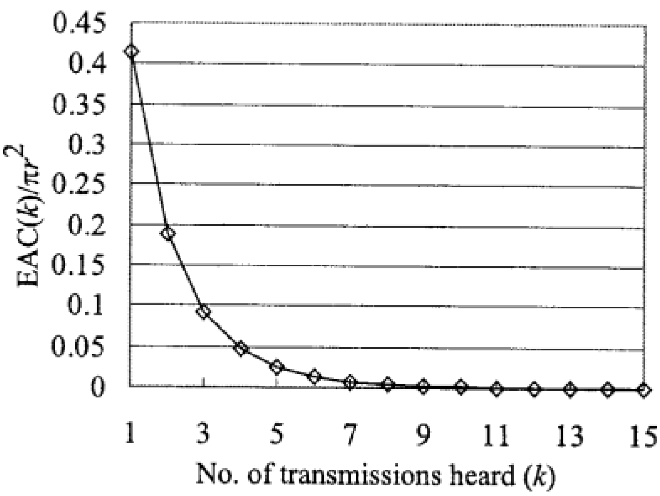

Figure 2-4. Analysis on redundancy: the expected additional coverage EAC(k).

2.1.4 Mechanisms to reduce redundancy, contention, and collision

as we have seen blind flooding can become very inefficient because of redundant, “superfluous” forwarding. In fact, superfluous, it increases link overhead and wireless medium congestion. In a large network, with heavy load, this extra overhead can have severe impact on performance and should be eliminated, where in spite of suppressing the duplicated route requests in some routing protocols as AODV and DSR, some of rebroadcasts may be redundant.

As a solution to alleviating the broadcast storm problem is to restrict hosts from rebroadcasting to reduce the redundancy, and thus, contention and collision. In the following, we present counter-based scheme to do so. This scheme differs in how a mobile host estimates redundancy and how it accumulates knowledge to assist in making its decision.

2.2 COUNTER-BASED SCHEME (CB)

Counter-based broadcasting was proposed in [5,9,10] as a mechanism to reduce redundant rebroadcast messages and solve the problems appeared in blind flooding The use of this scheme is to enable the mobile nodes to rebroadcast a message if the number of received duplicate packets is less than a threshold by taking in consideration the number of duplicate broadcast messages received. we will begin to use the counter-based scheme to know the amount of delivery.

In the counter-based mechanism, a random assessment delay (**RAD**) is set, a threshold C is determined and a counter $c \geq 1$ is formed on the number of times the broadcast message is received. During RAD, the counter c is incremented by one for each redundant message received and if $c > C$ when **RAD** expires, the message is dropped. Otherwise, it is rebroadcasted. In this approach, the predefined counter threshold **C** is the key parameter in this technique. We introduce two representative counter-based schemes used in broadcasting bellow:

2.2.1 Distance-Aware Counter-based broadcast

Sun et al.[33] proposed a DCB scheme in which node receiving a broadcast message determined a RAD based on the distance between itself and the broadcasting node :

$$\mathbf{RAD = rand[0,1] \times T_{max} \times \frac{(R^2 - D^2)}{R^2}}$$

Where Tmax the maximum RAD, R the maximum transmission range of the node, D be the distance between the broadcasting and receiving nodes, and the rand[0, 1] is a uniformly distributed random variable between 0 and 1.

C is defined as a fixed value. Because the coverage area of a node close to the broadcasting node is narrower than that of a node far from the broadcasting node, as shown in Figure 2-6, DCB mitigates the broadcast-storm problem by prohibiting the broadcast from node 2, thus providing high reachability.

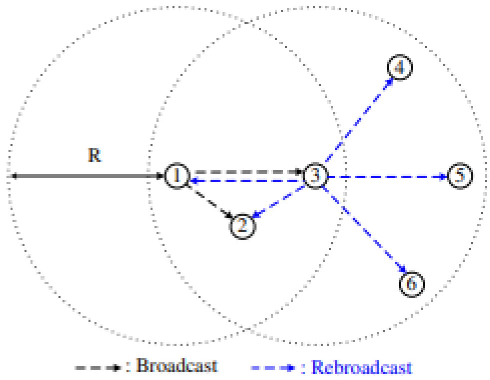

Figure 2-5. Distance-aware counter-based broadcast scheme.

2.2.2 Neighborhood-Aware Counter-Based Broadcast (NCB) Scheme

Humoud et al. [29] proposed an NCB scheme in which the RAD was determined based on the number of neighbor nodes. Let RF be a random factor . RF is set as one of two values: RF1 or RF2, where RF1 is less than RF2. When a node receives a broadcast-message, it checks the number of its neighbor nodes, n, against the average number of neighbor nodes, n_{avg}. If $n < n_{avg}$ ($n \geq n_{avg}$), the network is considered sparse (dense), and RF is set to RF1 (RF2). Thus, a node with a large (small) number of neighbor nodes determines a short (long) RAD as follows:

$$\textbf{RAD = rand[0,1]/RF}$$

In addition, a node with a large (small) number of neighbor nodes determines a small (large) C. In Figure2-7, the number of neighbor nodes of node 3 is greater than that of nodes 2 and 4. In this case, NCB mitigates the broadcast-storm problem by prohibiting the broadcasts from nodes 2 and 4, and can guarantee high reachability by rebroadcasting the broadcast-messages of node 3 to more neighbor nodes.

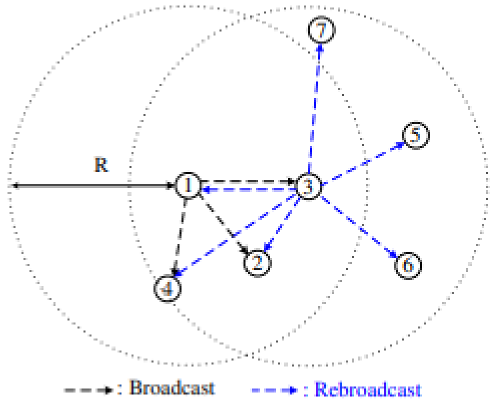

Figure 2-6. Neighborhood-aware counter-based broadcast scheme.

Ni et al. [41] have demonstrated that broadcast redundancy associated with simple flooding can be reduced while maintaining comparable reachability with a fixed parameters represented in a transmission radius (500 m), the broadcast packet size (280 bytes), the transmission rate (1M bits per second), and the DSSS physical layer timing (PLCP overhead, slot time, inter-frame separations, back-off window sizing, as suggested in IEEE 801.11). A geometric area called a *map* which contains 100 mobile hosts is simulated. A map can be of size 1 × 1, 3 × 3, 5 × 5,7 × 7, 9 × 9, or 11 × 11 units, where a unit is of length 500 m (the transmission radius) by using a counter based scheme with the value of C set to 2 or 6.

M.ould-Khaoua et all [28] have proposed an efficient counter-based broadcast scheme (ECBS), The use of ECS for broadcasting enables mobile nodes to make localized rebroadcast decisions on whether or not to rebroadcast a message based on both counter threshold and forwarding probability values. Essentially, this adaptation provides a more efficient broadcast solution in sparse and dense networks. In ECS, a node upon reception of a previously unseen packet initiates a counter *c* that will record the number of times a node receives the same packet. Such a counter is maintained by each node for each broadcast packet. After waiting for a random assessment delay (RAD, which is randomly chosen between 0 and Tmax seconds), if *c* reaches a predefined threshold *C*, we inhibit the node from this packet rebroadcast. Otherwise, if *c* is less than the predefined threshold, *C*, the packet is rebroadcast with a probability *P* as against automatically rebroadcasting the message in counter-based scheme.

The use of a rebroadcast probability stem from the fact that packet counter value does not necessarily correspond to the exact number of neighbors of a node, since some of its neighbors may have suppressed their rebroadcast according to their local rebroadcast probability. Thus, the selection of an optimal forwarding probability is vital to the performance of our scheme, they opt for a rebroadcast probability of 0.65.

CHAPTER 3: Simulation Frameworks and Environments

In this chapter we represent and analyze the state-of-the-art simulation frameworks, environments and techniques, in order to evaluate their sufficiency to our research study. To understand the choice made, we will begin by introducing the concept of simulation, her importance and the different simulation techniques available. Then, some of the known simulation tools, frameworks and techniques are described, followed by a comparison of these same tools. In the last section, the chosen simulator will be analyzed, discussed and its selection will be justified.

3.1 SIMULATION

Simulation is the process of learning by doing. Whenever there is something new in the world, we try to analyses it first by examining it and in the process get to learn a lot of things. This entire course is called as Simulation.

Correlating to this process, in order to understand all the complexities one need to model the entire role-play in form of computer simulation, the need is to build artificial objects and assign them roles dynamically.

Computer simulation is the designing of a theoretical physical system on a digital computer with emphasis on model designing, execution and analysis. After creation of the model the most important step is to create a computer program for updating the state and event variables through time (or event scheduling). If the simulation is executed successively in parallel computers, it is called Parallel (or Distributed) simulation.

Network simulators have been developed in order to allow researchers and companies to test their models and ideas without the troubles and cost of performing real implementations of these systems. But simulation techniques have been used for a long time in order to test and study ideas and models, and make development easier. Simulators try to recreate the environment using theoretical models, such as physics equations, mathematical formulas or the behavior of a machine.

Network simulators must allow parameterization in order to test different scenarios with respect to variables like the medium, technologies, protocols and mobility.

There are plenty of simulation tools and techniques available, and also many different types of simulation, which will be described next.

3.1.1 Why simulation?

Simulation has proven to be a valuable tool in many research fields where analytical methods are not applicable and experimentation is not practical, also, it provides a reasonable trade-off between the accuracy of observation involved in a test-bed implementation and understanding provided by analytical model.

For studying and analyzing the behavior of network algorithms on MANETs, simulation framework are a must. Very often, the most interesting scenarios and problems scale are incompatible with actual physical experimentation with devices like multiple devices required and complex physical deployment.

3.1.2 Type of simulation

There are three main kinds of simulators: real time, continuous and discrete.

Real-time simulators**:** real time simulators are good for cases where the event time is pertinent, like in video games or some controller tuning. This kind of simulator may be useful to perform time sensitive simulation. For example, if someone wants to use virtual machines or real devices, connected to each other over a simulated network in order to exchange time sensitive data. In cases like this, if the simulation does not happen in real-time, there might be problems with the software running on the devices. This type of simulation is usually less scalable than discrete simulation, since all events have to happen in real-time, and this can be computationally very expensive.

Continuous simulators**:** it is a computer model of a physical system which continuously tracks system response according to a set of equations. These models are mostly used in physics, to simulate phenomenon such as rocket trajectories, robotics, etc.

Discrete event simulators**:** in this type of simulation, models are created to represent a sequence of events in time where each event occurs at a particular instant, and it make a change in the system. The main advantage of this kind of simulation is that when an event happens, we skip right to the next one, without having to wait between them. This system of events differentiates this simulation from the continuous.

3.1.3 Simulation Frameworks

Next we describe and analyze several network simulation frameworks, and then make a decision for which one is the most adequate for our research.

Some simulators are fully discrete, such as NS-2, others can behave as both discrete and real-time, NS-3 and OMNeT++, and finally there are some that are only real-time simulation tools, such as Mac802.11 and WDSim.

OMNeT++

OMNeT++[58] is an extensible, modular, component-based C++ simulation library and framework. The first version of this software was released in 1997, and many independent groups have been developing components for this tool.

Despite it is not intended for network simulation, the OMNeT++ framework has been gradually extended to do so and is now extensively used by the scientific community.

The framework is based on the Eclipse IDE, which offers a graphical runtime, and a host of other tools. Its modules are written in C++, and are then assembled into larger components using an higher-level language (NED). There are plenty of extensions ranging from real-time simulation, network simulation, mobility, and several other things.

The INET Framework, is used in OMNeT++. This framework can be seen as the standard protocol model library. It contains models for the Internet stack, link protocols (both wireless and wired), support for mobility, and some MANET protocols. This framework is maintained by the same team as OMNeT++, and accepts patches and new models developed by the community. This framework is also used as a basis for some other tools, such as OverSim, which implement several peer-to-peer overlay algorithms, or Veins which simulates Inter-Vehicular Communications.

Other frameworks include the MiXiM, which is a modeling framework created for fixed and mobile wireless networks, mainly focus on the lower levels of the protocol stack, and Castalia that is a simulator for Wireless Sensor Networks (WSN), Body Area Networks (BAN), and in general networks of low power devices.

NS-2

The Ns-2 is one of the most popular discrete event network simulation tools and its architecture is organized according to the OSI reference model. Although it was originally designed for wired networks, Ns-2 has been extended for simulating wireless networks, including wireless LANs, mobile ad hoc networks (MANETs), and sensor networks. It is a popular and powerful network simulation tool, and the number of users has increased greatly over the last decade [60]. For example, 35 of the 80 simulation-based MANET papers published in the 2000-2005 ACM MobiHoc proceedings (i.e. about 43.8%) used Ns- 2 [60]. This is due to the fact that it is freely available, open source and includes detailed simulations of important operations of such networks [59].

Considering that we choose the NS2 as a main simulator in our research we will described it in detail in next section.

NS-3

NS-3 is a recent open-source discrete-event network simulator developed with the intent to replace NS-2, and targeted primarily for research and educational use. This simulator is among the best available, and is one of the most used network simulators nowadays. It was intended as a substitute for *NS-2*, and was developed from scratch in both C++ and Python. Most of the models that existed by default in the *NS-2* were also ported to NS-3. Many more models have since been developed specifically for this tool.

The *NS-3* is open source, being developed by a very active community, releasing updates every 2-3 months. At the moment, this simulator is capable by default of simulating Wi-Fi, WiMAX, LTE as IP based wireless networks, Point-to-Point, CSMA and other wired ways, and even non-IP based wireless networks, such as ZigBee (802.15.4).

Regarding the Wi-Fi communications, the *NS-3* offers models for the Wi-Fi physical layers 802.11 a/b/g/n at both 2.4 and 5.0GHz, QoS-Based ECDA 802.11e, plenty of propagation loss and delay models such as constant-rate or Log-Distance, various control rate algorithms such as Aarf or ConstantRate and even support for the 802.11e (MESH). This simulator is also good to test MANETs, since it supports a large range of mobility and building models, and some MANET routing algorithms, such as AODV or OLSR.

The models used for Wi-Fi communications (range, propagation loss, SNR) are also very well known, and are seen by the scientific community as very reliable. Although NS-3 is a discrete-event simulator, it also features a real-time scheduler, that facilitates a number of “simulation-on-the-loop” use cases for interacting with real systems. It is also possible to use a “tap-bridge” network device, to connect a simulated network to a real application or a virtual machine.

Finally, a “Direct-Code Execution” environment is being developed for the *NS-3*. It allows to run real applications and kernel code, as for example a Unix ping program instead of one developed specifically for the framework, directly on the platform.

The main disadvantage of the *NS-3* is the fact that there are still some communication protocols that have not been ported, such as Bluetooth, the steep learning curve, the fact that some 802.11 extensions and protocols, such as 802.11z (TDLS) are not implemented and the lack of support for Wi-Fi Direct simulation. This can be surpassed by the fact that being an open-source project, anyone is allowed to modify it in any way desirable, although this may bring consequences, because for a theoretical model to be recognized, it needs a much foundation and testing.

WDSim

WDSim is a framework developed to simulate the Android Wi-Fi Direct API. This framework consists of two separate modules. To simulate the Wi-Fi Direct protocol and Network, there is a console that enables developers to control some properties of the simulation, such as adding devices, establishing neighborhoods and moving devices in and out of reach of each other.

The second component of this framework are virtual machines that run android applications. Each of the virtual machines must have local IP addresses, and allow connections on specific ports. An android API is available to enable the use of the WDSim framework by applications.

Although this simulator looks promising, its implementation, still lacks many components that are important when performing realistic simulations. The Wi-Fi Direct protocol is over simplified, ignoring the group formation steps, there is no propagation loss models implemented, the mobility is very limited allowing only devices to be within or outside of the range and there is no DHCP server on the Group Owner, which means all IPs have to be hard-coded on the simulation set.

3.1.4 Simulator Comparison

In order to compare the existing simulation alternatives and be able to select a simulation tool suitable for our research, we select a set of relevant features that allowed us to classify and to distinguish the tools among themselves.

The feature criteria chosen are the following:

- **Source Type** - Whether the code is open source or commercial.
- **Coding Language** - Programming Language used to write models and applications.
- **Development Status** - Whether the tool is being updated or the development has stopped.
- **CPU Usage** - Whether the tool is CPU intensive or not.
- **Memory Usage** - Whether the tool consumes high amounts of memory or not.
- **Performance** - How it performs while running simulations.
- **Mobility Support** - Whether it supports mobility or not.
- **Protocols available** - What the amount of relevant protocols available by default.
- **Community status** - Whether the community behind the software is active.
- **Publication amount** - Whether it is a widely used tool in the scientific community.
- **Energy Models** - Whether or not the tool has energy models available.
- **Parallel Execution** - If the tool can perform parallel simulations.

The results shown in the table 3-1. were collected from different sources and from experimental data. Performance, CPU and memory usage data was gathered from the work done by Bilalb et al [61] and by Weingartner et al [62]. The number of publications was compiled from different sources, such as Google Scholar or the different simulation tools homepage.

Table 3-1 Comparison of Simulation Tools & Techniques

	OMNeT++	NS-2	NS-3	WDSim
Source Type	Open	Open	Open	Open
Coding Language	C++ NED	C++ TCL	C++ Python	Java
Development Status	Active	Open C++ TCL Stopped	Active	Unknown
Performance	High	Low	High	Unknown
CPU Usage	High	High	High	High
Memory Usage	Low	High	Low	High
Mobility Support	Yes	Yes	Yes	Partial
Protocols Available	Plenty	Plenty	Plenty	Few
Community	V.Active	L. Active	V.Active	L. Active
Publication Amount	High	V. High	High	Low
Energy Models	Yes	Yes	Yes	No
Parallel Execution	Yes	Yes	Yes	No

3.2 NS2

3.2.1 Definition

One of the first simulators, the *REAL Network Simulator* was modified to give origin to the *Network Simulator (NS)* which in turn, was updated to the *Network Simulator 2 (NS-2)*.

The NS-2 was the most used and published simulator for a long time. The reason for this, was that it was efficient, reliable, open-source and had a very large community that developed many modules to expand the default capabilities.

NS-2 is written in TCL and C++, but most of the simulation scenarios are written in TCL. By default, this simulator is capable of simulating TCP/UDP, routing, and broadcast protocols over wired and wireless (local and satellite) networks.

Although NS-2 does not simulate Bluetooth, there is an extension that enables Bluetooth simulation. UCBT implements a full Bluetooth stack, but the last version released only fully supported Bluetooth 1.1.

Parallel execution is also available via a community developed package called Parallel/Distributed NS (PDNS). PDNS was developed by the PADS research group at Georgia Tech, and its main goal was to allow a network simulation to be run in a parallel and distributed fashion, on a network of workstations.

3.2.2 THE COMPONENTS AVAILABLE IN NS-2

The NS-2 simulator contains the functionalities necessary for the study of medium access methods, point-to-point or multipoint routing algorithms, transport protocols, session, resource reservation, application protocols.

NS-2's network architecture is heavily based on the OSI layer model. The main components available for each layer and by category available in NS- 2 are following:

• Application: Web, ftp, telnet, traffic generator (CBR,…)

• Transport: TCP, UDP, RTP, SRM

• Routing (network layer): Static, dynamic and multipoint routing

• Queue management: RED, DropTail, Token bucket.

• Service discipline: CBQ, SFQ, DRR, queuing.

• Transmission system (link layer): CSMA / CD, CSMA / CA, point-to-point link

3.2.3 LANGUAGES USED IN NS-2

NS-2 uses two languages because it does two kinds of things. On the one hand, the use of C ++ is used to describe the inner workings of simulation components, which must be performed in a fast and efficient manner and give a greater computing power (C++ is for "data": per packet processing, core of ns , fast to run, detailed, complete control). On the other hand, the use of the OTCL(Object-oriented Tool Command Language) allows the definition of a network topology, the characteristics of the physical links, the specific protocols and the applications that one wants to simulate, the type of traffic generated by the sources, the events and the form of output that we want to obtain by the simulation(OTcl for "control": Simulation scenario configurations, periodic or triggered action, manipulating existing C++ objects, fast to write and change).

3.2.4 Features of NS2

So, we can resume features of NS2 in some points as follow :

1. It is a discrete event simulator for networking research.

2. It provides substantial support to simulate bunch of protocols like TCP, FTP, UDP, https and DSR.

3. It simulates wired and wireless network.

4. It is primarily Unix based.

5. Uses TCL as its scripting language.

6. Otcl: Object oriented support.

7. Tclcl: C++ and otcl linkage.

8. Discrete event scheduler.

3.2.5 NS-2 WORKING VIEW

As shown in Figure 3-1 a simulation program in NS-2 is designed by the OTcl script, using the NS simulator library (event planner objects, network component objects and network configuration help modules) to compile and simulate by the OTcl interpreter. NS produces one or more text files that contain detailed simulation data. The data can be used for simulation analysis or as an input to a simulation graphical visualization tool called a network animator (NAM).

A Tcl script do the following: Starts the event scheduler; Defines the network topology using the network objects; Indicates traffic sources when to start / stop the transmission of packets through the event scheduler.

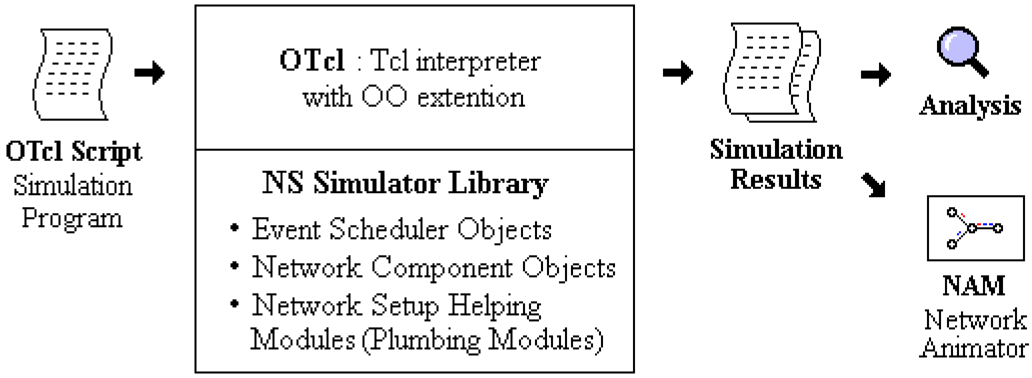

Figure 3-1. how NS2 works.

3.2.6 NS-2 ARCHITECTURE

Figure 3-2 shows the general architecture of the NS-2 simulator, In this figure, a general user (not an NS developer) can be seen standing in the lower left corner, designing and running Tcl simulations using simulation objects in the OTcl library. OTcl is the object oriented extension which is implemented on part of Tcl. Event planners (Event Scheduler) and most Network Component are implemented in C ++. C ++ is the heart of NS-2. Tclcl is the link between OTcl and C ++, and Tclcl (Tcl with classes), is the interface between C ++ and Tcl.

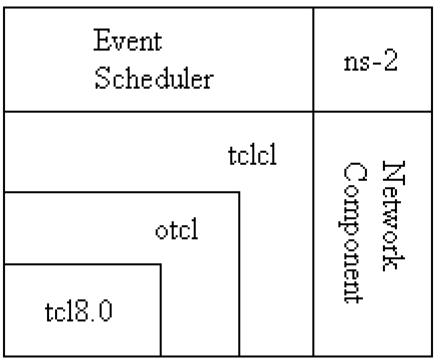

Figure 3-2. NS2 Structure

3.2.7 The network models under NS-2

3.2.7.1 Wired network simulation

Nodes and links are required in wired network simulation for creating topologies. The topology in NS-2 is basically made up of nodes and links. Agent can be attached to nodes and all nodes must be connected by links.

Nodes

A node plays two important roles in NS2. Like a router, it forwards packets to the link based on a routing table. Like a host, it delivers packets to the transport layer agent plugged into the port specified in the packet header. Nodes are defined in the Node class. A node is a collection of classifiers and agents. The classifier processes each segment of the received packets.

The links

Links between nodes are defined in the *Link* and *SimpleLink* class more precisely when it comes to connecting two nodes and forwarding packets. The link is mainly characterized by propagation delay and bandwidth. Several types of links are supported, such as point to point, broadcast or wireless links for mobility.

Queue management

Queue management and link delay simulation (server) are implemented in the *Queue* and *LinkDelay* classes respectively. As long as the server is busy transmitting a packet, no further transmission can take place. The duration of the transmission depends on both the length of the packet and the bandwidth of the link. The queues currently available in NS are: FIFO; RED buffer management; CBQ (priority and circular); … Etc.

The agents

The agent is an integral part of a node and are the end points to network layer packets; their role is to generate and receive packets. Currently NS has many agents: UDP, routing protocols, different versions of TCP, RTP,… etc.

Traffic generator

Associated with an agent that corresponds to the transport entity, an application notifies the join agent of the users' request. The Application class models the application in terms of a traffic source. The generation of traffic in NS can be done in two different ways and it is described in the Application class, it is possible to generate packets by a traffic generator (Traffic / CBR, Traffic / Exponential, Traffic / Pareto) or by simulation existing applications (FTP and Telnet).

Routing

The user must specify During a simulation a routing protocol, that is to say, tells the simulator how to build the routes between the nodes. NS offers three types of routing in a wired network: static routing, session routing, dynamic routing.

3.2.7.2 Wireless network simulation

The components of wireless networks are packet head, mobile nodes, wireless channels, transmissions and routing. Simulating wireless networks should configure mobile nodes, motion path, and scenarios.

Packet headers

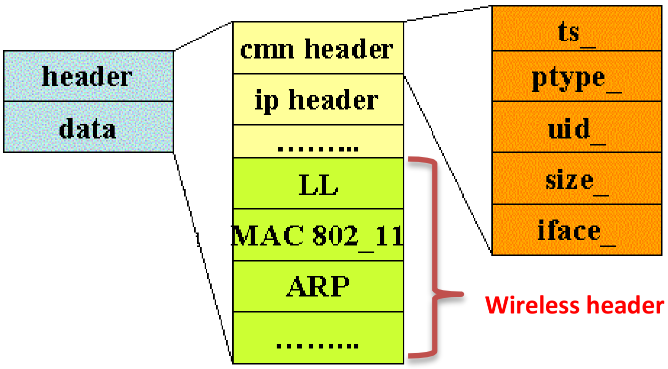

Figure 3-3. wireless packet format

From figure 3-3 we can know the main variables of the wireless header which are link layer (LL), MAC, type of channel, type of antenna and Interface Queue Type.

Mobile nodes

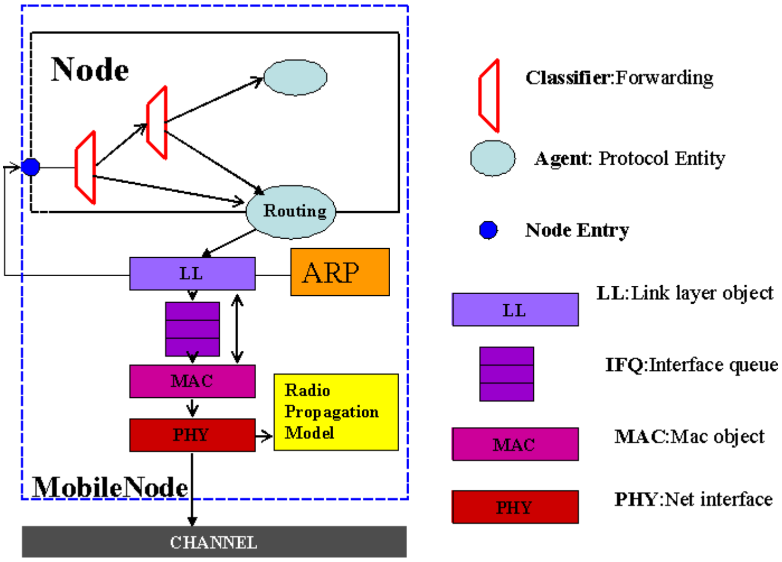

Figure 3-4.mobile node

Figure 3-4 shows the network components in the mobile node and the data path for sending and receiving packets. The mobile node needs the parameters of location (coordinates (x, y, z)) and movement (speed, direction, start point, end point, time, etc.).

The mobile node components are the link layer, the queue interface, MAC layer, the network interface, the propagation model, and an antenna.

a) Link layer

The Link Layer manages the transfer of data in and out of a network, preparing packets to be put on a wireless channel.

b) The queue interface

Interface Queue used to store packets that should be sent out and prioritize routing protocol packets.

c) MAC layer

Mac TDMA and IEEE 802.11 MAC layer protocols are used in NS2. The MAC layer used for managing access to the wireless channel.

d) Network interface

NS uses Phy / WirelessPhy for the implementation of interfaces. The goal is to simulate the hardware interface that a mobile node uses to access the channel. The Network Interface is used to send and receive packets over the wireless channel. The network interface submissive to collisions, the radio propagation model receives packets transmitted by other node interfaces in the channel.

e) Radio propagation model

The Radio Propagation Model used is *FreeSpace* attenuation for short distances and *TwoRayGround* for long distances.

f) Antenna

OmniAntenna and *DirAntenna* are used by mobile nodes as the type of antenna. And the antenna provides a good abstraction of wireless network simulation.

OmniAntenna in NS-2 is an Omni-directional virtual antenna system and *DirAntenna* in NS-2 is a virtual directional antenna system.

Wireless channel

The Wireless Channel simulates the transmission of packets at the physical layer. She has the responsibility of the receiver and decide if she accepts the packages.

Transfer and routing

Forwarding and routing in NS-2 is archived by a classifier object. Nodes in NS contain many different classifiers. An address classifier used to give packets to the port classifier. A port classifier, used to give packets to agents attached to the mobile node.

3.2.8 Why NS2 ?

1. Cheap- Does not require costly equipment.
2. Complex scenarios can be easily tested.
3. Results can be quickly obtained-more ideas can be tested in a smaller time frame.
4. Supported protocols.
5. Supported platforms.

6. Modularity.
7. Popular.
8. Improve flexibility.
9. Provide access to information.
10. Services regardless of geographic position.
11. Robust free network.
12. Both distributed & central network administration.
13. Quick integration.
14. Ns-2 implements the standard IEEE 802.11 Distributed Coordination Function (DCF) MAC protocol: In this standard the transmission of each unicast data packet is preceded by an RTS/CTS control packet exchange between communicating nodes to reduce the probability of collisions due to hidden terminals [63]. Each correctly received unicast data packet should be followed by an Acknowledgment (ACK) to the sender; otherwise the sender retransmits the packet a limited number of times (e.g. 7 times) until this ACK is received [57]. Broadcast packets such as RREQ packets, on the other hand, are not preceded by an RTS/CTS exchange nor acknowledged by their recipients, but they are sent only when the transmission medium is sensed as idle.
15. The Ns-2 simulator includes radio propagation models that support propagation delay, capture effects, and carrier sense [56]. The radio models use characteristics similar to the commercial Lucent WaveLAN technology with a nominal bit rate of 2Mb/s and a nominal range of 250 meters with an omnidirectional antenna. The radio propagation models in NS-2 include the free space propagation model, the two-ray ground reflection model and the shadowing propagation model.

3.2.9 Disadvantages

1. Real system too complex to model. i.e. complicated structure.
2. Bugs are unreliable.
3. It does not take all circumstances into consideration (like climatic conditions).

CHAPTER 4: Performance analysis of CB and BF

In this section, we presented the performance evaluation of the Counter-based broadcasting algorithm and blind flooding algorithm, Which was done by M.Oueld Khaoua et al in [44]. We have evaluated the performance using Ns-2 packet level simulator (v.2.29) and uses the ad-hoc networking extensions provided by CMU [21]. Our performance analysis is based on assumptions that have been widely used in the literature:

- All nodes participate fully in the broadcast protocol of the network. each node belong to the network should also be prepared to forward packets to other nodes in the network.
- Packets may be lost or corrupted in the wireless transmission medium during propagation. A node that receives a corrupted packet can detect and discards the packet.
- All mobile nodes are homogeneous (i.e. wireless transmission range and interface cards are the same).

At the MAC level, the 802.11b [22] protocol has been considered. 802.11b operates in the 2.4 GHz band designed for ISM applications. The physical radio characteristics of each node such as the transmit power, signal to noise and interference ratio and antenna gain, are chosen to mimic the commercial Lucent ORINOCO Wireless LAN PC Card [23] with a nominal bit rate of 5.5 Mb/s and a transmission range of 100 meters with an omnidirectional antenna. To gain more realistic signal propagation than with the deterministic free space or two-ray ground reflection models [24], the shadowing model is used as the radio propagation [25]. The actual movement of nodes are based according to random trip mobility model [26] in a field of 1000m x 1000m, “a generic mobility model that generalizes random waypoint and random walk to realistic scenario” [26] which uses a technique to sample the initial simulation state from the stationary regime (a methodology that is usually called perfect simulation) based on Palm Calculus [27] in order to solve the problem of reaching time-stationary. Unlike other random mobility models, Random trip reaches a steady-state distribution without a long transient phase and there is no need to discard initial sets of simulation observations. The simulation is allowed to run for 900 seconds for each simulation scenario. Other simulation parameters that have been used in our experiment are shown in Table 4-1.

Table 4-1. SIMULATION PARAMETERS

Simulation Parameter	**Value**
Simulator	NS2 (v.3.35)
Transmission range	100 meters
Bandwidth	5.5 Mbps
Interface queue length	50
Packet size	512 byte
Traffic type	CBR
MAC type	802.11b
Topology size	1000 x 1000 m^2
Number of nodes	20,40,…., 200
Simulation time	900 sec
Counter threshold (C)	3
Maximum Speed	5 m/s
Broadcast Injection rate	1, 10, 20, …, 70

4.1 PERFORMANCE METRICS

We have evaluated the algorithms using the following performance metrics:

4.1.1 Reachability

Is the percentage of network mobile nodes that receive any given broadcast packet over the total number of mobile nodes that are reachable, directly or indirectly[30]. In a network without division, the flooding approach guarantees that all nodes can receive the broadcast packets at the expense of extra traffic caused by redundant rebroadcasts. In reality, however, redundant rebroadcasts also contribute to possibility of packet collisions that may eventually cause packet drops, thus adversely affecting the reachability. We study the reachability in the context of the AODV routing protocol.

4.1.2 Retransmitting Nodes

Is total number of nodes that have rebroadcast a given broadcast packet.

4.1.3 End-to-end delay

The elapsed time between when a broadcast is initiated and its reception by the last node in the network. This delay includes all possible delays caused by buffering during broadcasting delay, queuing at the interface queues and retransmission delays at the MAC, propagation and transfer times.

4.1.4 Collision rate

The total number of broadcast packets dropped by the MAC layer as a result of collisions per unit simulation time.

4.2 MOBILITY MODELS

Is the most important advantage of the MANET and it is the most challenging problem to provide reliable high performance communication , the mobility models used to describe the movements of the mobile nodes, defining the position, speed and acceleration of the nodes at every instant in the simulation scenario, these mobility models can be classified in :

- Entity mobility models (independent movements)
- Group mobility models (dependent movements)

We have basically two types of mobility models that are used in the simulation of networks: **traces** and **synthetic** models.

Traces mobility models are those mobility patterns that are observed in real life systems. In the case of a large number of nodes and a long observation period, they provide accurate information. New ad hoc network environments cannot be easily modeled if traces have not yet been created. In such a scenario, synthetic models can be used.

Synthetic models try to represent the behaviors of mobile nodes realistically without the use of traces. In the case of a synthetic model, the models need to be designed in such a way that they should change the speed and direction in a reasonable time slot. For example, we would not want the mobile nodes to travel in straight lines at constant speeds throughout the course of the entire simulation that does not match the behavior of the real nodes. Figure 3.1 shows a general classification of mobility models :

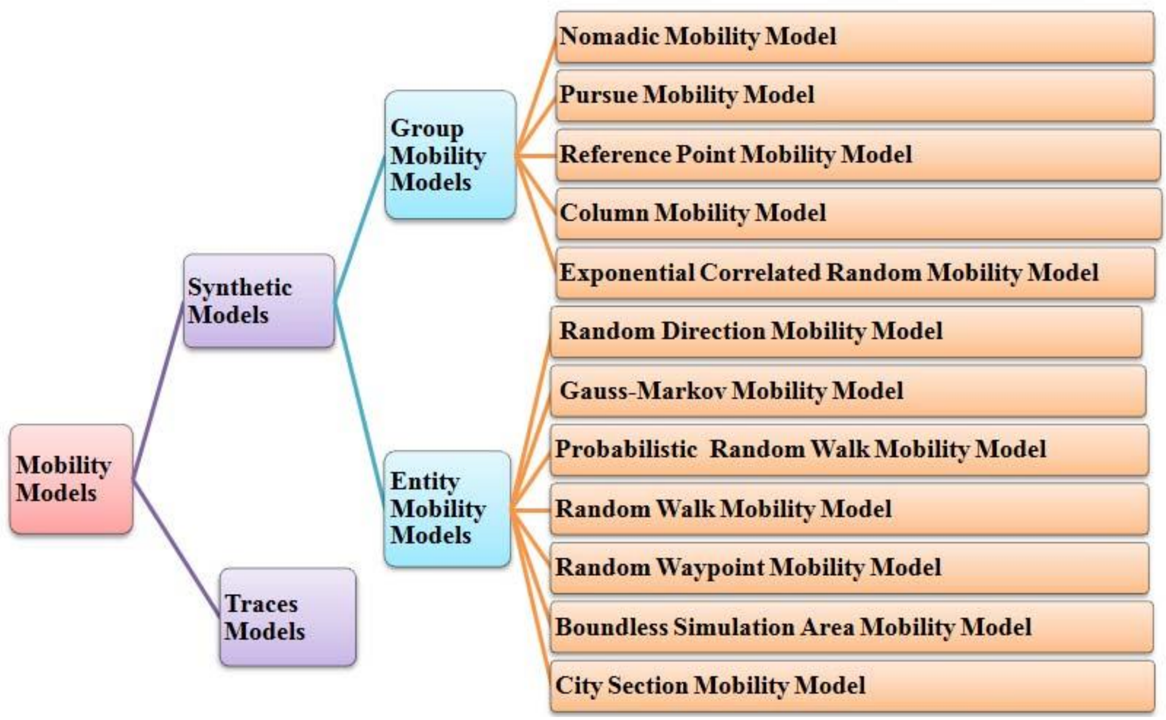

Figure 4-1.Mobility Models

we present an overview of the mobility model that used in the performance evaluation of our schemes, it is the Random Waypoint Mobility Model (RWP).

4.2.1 Random Waypoint Mobility(RWP)

The most popular mobility model used is simulation scenarios, it consist of a collection of nodes placed randomly inside a limited simulation area, each node select a random destination inside the simulation area and travels towards it by a certain speed, when he arrives to its destination, the node pauses for some time (called pause time) before it chooses another random destination and repeat the process, the mobility of every node is independent to that of others.

Figure 3.2 shows an example of node’s movements using the random waypoint model; the node starts from a random position (x1, y1), after a pause time he will move towards a random chosen position (x2, y2) with a speed between 0 and 5 m/s, and so on …

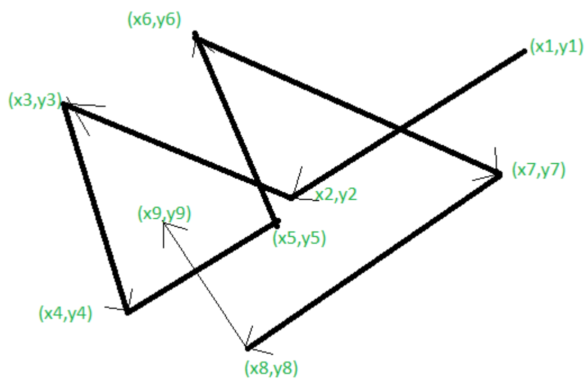

Figure 4-2.Traveling pattern of a mobile node using the random waypoint mobility model.

This mobility model has been widely used by different researchers because it can be simplified. For example, the random waypoint mobility model is used without pause times. In most of the performance evaluations using the RWP mobility model, the mobile nodes are initially distributed randomly around the entire simulation area. This initial random distribution of the nodes is not the same in which nodes distribute themselves while moving.

The average mobile node neighbor percentage is the cumulative percentage of total mobile nodes that are a given mobile node's neighbor. For example, if the network contains 50 mobile nodes and a node has 5 neighbors, then the node's current neighbor percentage is 10%. A node is considered as a neighbor of another node if it is within the node's transmission range.

4.3 SIMULATION WORK

The simulation work contain a pairs of files to each broadcasting protocol, one C++ file for packets controlling and the other Tcl script for animation. Now, we will present some lines of codes descripting some techniques and functions used for broadcasting programming:

The first class used is to bind C++ classes to the Otcl class:

```
static class FloodHeaderClass : public PacketHeaderClass {
  public:
    FloodHeaderClass() : PacketHeaderClass("PacketHeader/Flood",
                                            sizeof(hdr_flood))
  {
    bind_offset(&hdr_flood::offset_);
  }
} class_floodhdr;

static class FloodClass : public TclClass {
  public:
    FloodClass() : TclClass("Agent/Flood") {}
    TclObject* create(int, const char*const*) {
      return (new FloodAgent());
    }
} class_flood;
```

Also, need to create FLOODAGENT to bind C++ and Otcl variables:

```
FloodAgent::FloodAgent() : Agent(PT_FLOOD) {
   This binds the C++ and OTcl variables.
  bind("packetSize_", &size_);
  bind("off_flood_", &off_flood_);

  // counter for packets
  sentDataPackets = 0;
  receivedDataPackets = 0;
  accum_header_length = 0;
  accum_queue_length = 0;
  queue_count = 0;

  // link layer and node handles
  ll = NULL;
  node = NULL;

  // Indicate if you want output or not:
  Verbose = true;

  return;
}
```

the received packet will be rebroadcasted for the first time (in Blind-flooding) using the **SendBroadcastPacket()** function

```
if (Verbose)
  {
    cout << "Receive: " << hdrcmn->uid_ << " to " << floodhdr->toAddr()
         << " from " << hdrip->saddr() << endl;
    cout << " rebroadcast." << endl;
  }
floodhdr->route_[floodhdr->hops()] = this->addr();
floodhdr->hops()++;
SendBroadcastPacket(pkt);
if (Verbose)
  {
   cout << "Time:  " << Scheduler::instance().clock() << endl;
   cout << "*****************************************************" << endl
        << endl;
  }
```

if the packet is received before it will be dropped(**free (pkt)**), for that we use a condition :

```
if (this->dupRcvdPacket(hdrcmn->uid_)
     || this->dupSentPacket(hdrcmn->uid_))
  {
   if (Verbose)
    {
     printPacketHeader(pkt);
     cout << "Duplicate packet from " << hdrcmn->prev_hop_
          << ", drop it." << endl;
     cout << "Returning from recv early" << endl;
     cout << "Time:  " << Scheduler::instance().clock() << endl;
     cout << "*****************************************************" << endl
          << endl;
    }
   Packet::free(pkt);
   return;
  }
```

In Counter-based it's pretty much the same , just using of the threshold and the RAD (using jitter timer) :

```
// Default Counter Threshold.
#define CBFLOOD_COUNTER_THRESHOLD 3
```

```
cb_threshold = CBFLOOD_COUNTER_THRESHOLD;
```

```
#define  CBFLOOD_JITTER 10.0
```

```
cb_jitter = CBFLOOD_JITTER;
```

CONCLUSION

This thesis has presented a performance evaluation of broadcast communication in wireless mobile Ad-hoc network (MANETs) where nodes were static and moving according to random waypoint mobility model. where we have choose two approaches were studied and compare between them, the first is blind flooding, the simplest broadcasting mechanism, simplest broadcasting mechanism, but its simplicity it could potentially leads to high redundant retransmissions causing high channel contention and thus excessive packet collisions in the network. This phenomenon referred to as broadcast storm problem has been shown to greatly increase the network communication overhead and end-to-end delay. Several approaches have been proposed as a solution to mitigate the impact of this inherent phenomenon, include counter-based, distance-based, location-based, cluster-based broadcasting and others, most of these techniques are inadequate in reducing the number of redundant retransmissions while still guaranteeing that all nodes receive the packet. However, we have choose the counter-based scheme for the performance evaluation according to broadcasting performance metrics represented in number of retransmitting nodes, reachability, average collision rate and End-to-End delay.

Using NS2, the simulation scenarios consist of two different settings, each designed specifically to assess the impact of a particular network condition on the performance of the algorithms. First, the impact of network density is assessed by deploying 20-200 nodes over a fixed square topology area of 1000m x 1000m. The second simulation scenario investigates the effects of an offered load on the performance of the broadcast schemes by varying the number of packet injection rate for each simulation scenario.

Simulation results show that the counter-based broadcast scheme achieves superior performance compared to the blind flooding in terms of retransmitting nodes, collision rate, and end-to-end delay without sacrificing reachability.

Although, the performance of all the schemes degrades with increased broadcast injection rate, the proposed CB shows a better resilience in high broadcast injection rate settings as it manages to reduce the channel contention and packet collision by minimizing the redundant retransmissions.

This thesis has evaluated the performance ofcounter-based and blind-flooding in the context of pure broadcast scenario. However, investigating the performance merits of these broadcasting algorithms in real applications, such as route discovery process is lacking. As a continuation of this research in the future, it is interesting to implement and evaluate the performance of CB and other existing schemes as a route discovery mechanism in some reactive routing protocols.

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