CONTENTION AND POWER AWARE ROUTING PROTOCOL FOR MOBILE AD-HOC NETWORKS

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DEDICATIONS

To my soul mate and the accompanier of my journey and life, To whom her sole is now praising in the vast realm of Allah (The Almighty), may Allah shelter her with his endless humbleness and forgiveness;
To my sister Soukina (Um Aya).
May Allah accommodate her along with her daughter
Bushra
in the most exalted of places amongst the righteous ones.

To my inspirer, teacher and backer,
To my father.

To my spring of ultimate love and ample giving,
To my mother.

To my brothers, sisters, and my fiancé.

To my adored little Aya and Hala,
may Allah (oft-forgiving, most merciful) be humble with their mother and accept her good deeds and forgive her.

To my darling grandmothers, and my two passed-away grandfathers, may Allah be forgiving towards them.

To all my beloved ones, I dedicate this thesis

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LIST OF ABBREVIATIONS

AODV	Ad hoc on-demand Distance Vector Routing
AODVCP	Contention and Power Aware Ad hoc on-demand Distance Vector
AP	Access Point
BLP	Battery Level Percentage
BSS	Basic Service Set
CBR	Constant Bit Rate
CQR	Contention and Queue aware Routing protocol
CMMBR	Conditional max-min battery capacity routing
COMPOW	Smallest Common Power protocol
CSLAR	Contention Sensitive Load aware routing protocol
CSMA	Carries Sense Mutable Access
CTS	Clear To Send
CW	Contention Window
DCF	Distributed Co-ordination Function
DIFS	Distributed Inter Frame Space
DLAR	Dynamic Load Aware Routing protocol
DSR	Dynamic Source Routing
FTP	File Transfer Protocol
IEEE	Institute of Electrical and Electronic Engineers
IR	Improvement Ratio
GloMoSim	Global Mobile information system Simulation library
LBAR	Load Balanced Ad hoc Routing protocol

LEAR	Localized Energy Aware Routing protocol
LSR	Load Sensitive Routing protocol
MAC	Message Authentication Code (MAC)
MAC-layer	Medium Access Control
MANET	Mobile Ad hoc Network
MCL	Minimum Contention Time and Load Balancing routing protocol
MWNs	Multi Hop Wireless Networks
NAV	Network Allocation Vector
RP	Remaining Power
RREP	Route Replay
RREQ	Route Request
RTS	Request To Send
RX	Receiving mode
TCP	Transmission Control Protocol
TH	Power Threshold
TX	Transmitting mode
UDP	User Datagram Protocol
WLAN	Wireless Local Area Network
WRP	Wireless Routing Protocol
ZRP	Zone Routing Protocol

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ABSTRACT

An ad-hoc network is a collection of wireless mobile nodes dynamically forming a temporary network without the use of any existing network infrastructure or centralized administration. Many Routing protocols have been proposed for Mobile ad-hoc network, most of them do not consider contention time that occur in medium reservation procedure. Large contention times can be more critical than hop count in determining end-to-end delay. Also the low energy nodes are critical and may cause a network partition.

In ad-hoc networks, traffic concentration on some mobile nodes lead to long queuing delays and inefficient power consumption. In this thesis, we propose an ad- hoc routing protocol named AODVCP. Our protocol selects a route with minimum contention among many possible routes between source and destination in the route selection procedure while each node with this route should have remaining power more than specific threshold. AODVCP distributes traffic and power throughout the network.

We have compared the proposed AODVCP and the Ad-hoc On-demand Distance Vector (AODV) routing protocol. The performance parameters that we use are the traffic load and the collisions. Simulation results show that AODVCP outperforms AODV in term of average end-to-end delay, average end-to-end throughput, discovery overhead and network life time. The average improvement ratio of end-to-end throughput is 23%, the average improvement ratio of end-to-end delay is 67%, and the average of improvement ratio of routing overhead and network life time are 41% and 78% respectively.

1. INTRODUCTION

1. Introduction

1.1 Overview:

Wireless communication between mobile users is becoming more popular than ever before. This is due to recent technological advances in laptop computers and wireless data communication devices, such as wireless modems and wireless LANs. Ease of use, increased computation power, reduced cost, and mobile capabilities are the reasons that lead to rapid growth in wireless network (Hong et al., 2002).

Wireless network is a telecommunication network whose Interconnections between nodes is implemented without the use of wires. Wireless telecommunications networks are generally implemented with some type of remote information transmission system that uses electromagnetic waves, such as radio waves, for the carrier and this implementation usually takes place at the physical layer of the network (Tanenbaum, 1997).

Wireless local area networks (WLANs) were developed as a mean to provide high bandwidth to users in a limited geographical area. WLAN is based on radio waves to enable communication between devices in a limited area, also known as the Basic Service Set (BSS). This gives users the mobility to move around within a broad coverage area and still connected to the network. All components that can connect into a wireless medium in a network are equipped with Wireless Network Interface Cards (WNIC) (Flickenger et al., 2006).

There are two distinct approaches for enabling wireless communication between two hosts. The first approach is infrastructure; the network is divided into cells called Basic Service Set (BSS) were each cell is controlled by an Access Point (AP) that provides the communication between the mobile nodes in the cell and other networks (Crow et al, 1997). Figure 1.1 shows a sketch of infrastructure network.

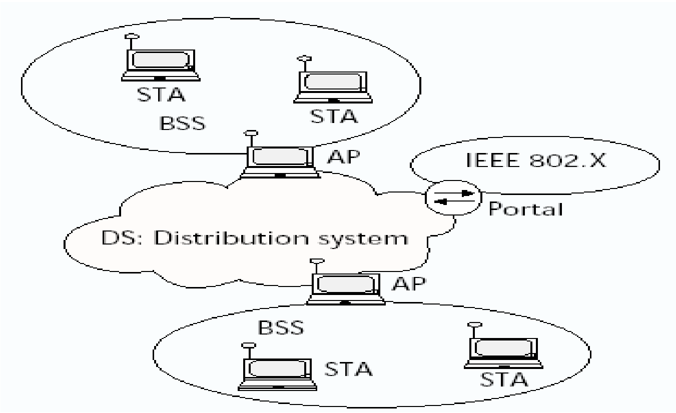

Figure 1.1: A sketch of infrastructure network (Crow et al, 1997)

The second approach is infrastructure-less which is called mobile ad-hoc networks (MANET). MANETs are collections of mobile nodes that dynamically forming a temporary network without preexisting network infrastructure or centralized administration. Mobile nodes can be arbitrarily located and are free to move randomly at any given time. Each node participating in the network acts both as host and a router and must therefore be willing to forward packets for other nodes. Figure 1.2 shows a sketch of an ad-hoc network (Crow et al, 1997).

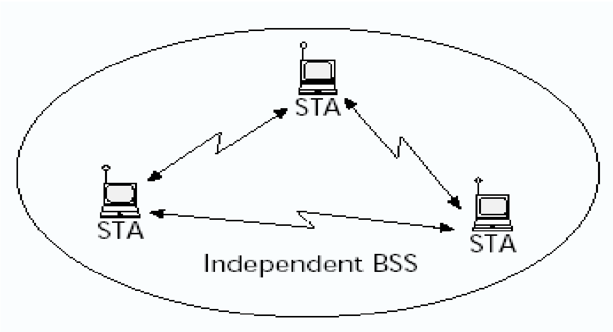

Figure 1.2: A sketch of infrastructure-less network (Crow et al, 1997)

1.2 MANET Applications

Recently, Mobile ad-hoc networks have received a great attention due to its wide applications. Ad-hoc networks are suited for use in situations where an infrastructure is unavailable or to deploy one is not cost effective. Therefore, various applications and implementations of Ad-hoc networks such as military, emergency, and conferencing applications (Latiff et al., 2005). The following points illustrate some of these applications:

- Military Applications: One of the hardest and largest applications are utilized in military environments. The way wars are being fought today has changed drastically. There is no fixed infrastructure when operating in a foreign country. Even when defending own country, these infrastructures are most likely to be damaged or destroyed by enemy forces, so it is more critical than in civilian applications.
- Emergency Services: Another huge public application may be in the area of emergency services (Firefighters, Police, etc), sometimes they have to operate in areas where no information infrastructure is present and

operations still need to be coordinated. MANET can be used in rescue operation for disaster support effort.

- Conferencing Applications: MANET is useful in conferences when there are no fixed office network infrastructures. MANET will enable exchanging data and supporting cooperative work.

1.3 MANET Properties

MANET have several properties that differentiate it from the traditional wired network in many aspects. The first one is the limited bandwidth; this important feature affects the nodes and the network lifetime. For wired network, the available Bit rates are 1,000 Mbit/s, while a limited data rates are offered with wireless networks. No infrastructure is provided so all the participating nodes in the wireless networks act as a router and a forwarder to other nodes. Since wireless networks enable nodes to move freely in the environment, a continuous breaking and rebuilding of links in the network makes the network topology vary over time. In addition power consumption is an important factor in wireless networks since battery limitation affects the power of the signals used in the transmission operations (radio range) (Crow et al, 1997).

The capacity of WLANs should ideally be close to that of wired networks. However, the physical limitations and limited available bandwidth make WLANs operate at data rates between 1–20 Mb/s. The lack of infrastructures in wireless network makes it vulnerable to many types of attacks. In a wired network, the transmission medium can be physically secured, and access to the network is easily controlled. With wireless network, this is more difficult to secure due to the fact that transmission medium is open to anyone within the geographical range of a transmitter. Data privacy is usually accomplished over a radio medium using encryption. While encryption of wireless traffic can be achieved, it is usually at the expense of increased cost and decreased performance (Crow et al, 1997) and (IEEE 802.11, 2007).

MANET's environment suffers from classical challenges including limited bandwidth since all wireless communication links share the same medium thus causing data interference; these interferences reduce the efficiency of the network. Limited battery power is also a challenge since most mobile devices are battery powered which is easily drained by routing calculations and sending control and data packages through the network. Other hazards are short radio coverage, frequent topology changes, and limited security. Finally wireless communication is much more vulnerable to security issues (denial-of-service attacks, bugging, etc.) than hard-wired connections since the physical media cannot be protected from unauthorized access (Hong et al., 2002).

1.4 Routing in MANET

Routing protocols of mobile ad-hoc network require different approaches from existing Internet protocols, since most of the existing Internet protocols were designed to support routing in a network with fixed structure. New demands have been imposed on the routing protocol for the ad-hoc network due to it unique characteristics especially the dynamic topology which changes as nodes change locations (Crow et al, 1997).

The routing protocol must quickly adapt to the dynamic changes in the topology. Nodes in an ad-hoc network can consist of laptops and personal digital assistants with limited resources such as CPU capacity, storage capacity, battery power and bandwidth. Therefore, the routing protocol should try to minimize control traffic, such as periodic update messages (Crow et al, 1997).

Traditional routing protocols according to (Kuosmanen, 2002) are classified as proactive routing protocols (Table-Driven) and reactive routing protocols (On-Demand). Table-driven protocols are one of the old ways of acquiring routing in mobile ad-hoc networks. These protocols maintain consistent overview of the network were each node uses routing tables to store the location information of other nodes in the network. This information is used to transfer data among various nodes of the network. To ensure the freshness of the routing tables, these protocols adopts different sorts of mechanisms. One of the adopted methods is broadcasting "hello," a special message containing address information, at fixed intervals of time up on receiving this message, each node updates its routing tables with fresh locations information of other participating nodes. Table-driven protocols might not be considered an effective routing solution for mobile ad-hoc network.

Nodes in mobile ad-hoc networks operate with low battery power and with limited bandwidth. Presence of high mobility, large routing tables and low scalability result in consumption of bandwidth and battery life of the nodes. Moreover, continuous updates could create unnecessary network overhead. Some of the popular table-driven protocols for mobile ad-hoc network include Destination Sequence Distance Vector routing protocol (DSDV), Wireless Routing Protocol (WRP) and Cluster-head Gateway Switch Routing (CGSR) (Larry and Bruce, 1999).

Other family of routing protocols for mobile ad-hoc network are on-demand routing protocols. With on-demand protocols, if a source node requires a route to the destination for which it does not have routing information, it initiates a route discovery process that goes from one node to the other until it reaches the destination or an intermediate node that has a route to the destination. It is the responsibility of the route request receiver node to reply back to the source node about the possible route to the destination. The source node uses this route for data transmission to the destination node. Some of the best known on-demand protocols are Ad-hoc On-demand Distance Vector routing (AODV), Dynamic Source Routing (DSR) and Temporary Ordered Routing Algorithm (TORA) (Larry and Bruce, 1999).

Distance vector and link-state is the most popular routing algorithm for the mobile ad-hoc network. Link-state routing is a shortest path algorithms were each node periodically broadcasts the cost of the link of its neighbors by using flooding. Nodes that receive this information use it to update its routing table and to calculate the best next hop from it to every possible destination in the network by applying a shortest path algorithm. Network topology views can be inconsistent in link state, which is a consequence of the long propagation delay and partitioned network which leads to formation of short-lived routing-loops. In distance vector protocols, each node periodically broadcasts the shortest distance to every other node on the network to its neighbour only, receiving nodes applies the received information and updates its routing table using the shortest path algorithm. Distance vector protocols are more computation efficient, easier to implement and require less storage space than the link state protocols. In distance vector the nodes choose their next hop in distributed manner and by using information that can be stale, which leads to formation of both short-lived and long-lived routing loops (Larry and Bruce, 1999).

The Ad-hoc On Demand Distance Vector Routing protocol (AODV) is classified as an on-demand protocol since it builds routes using route request / route reply query cycle, it also a loop free, self-starting, and scales to large numbers of mobile nodes (Perkins and Royer, 1999).

1.5 Power Consumption in MANET

One of the key challenges in MANET's environment is the limited node's battery power. Despite the advancement in battery technology in reducing size and/or increasing power capacity, power consumption remains the important factor to be considered. (Forman and Zahorjan, 1994).

Most of mobile devices run on lithium-ion, rechargeable batteries. These batteries have a lifetime of a few hours of active workload and about 1-2 days of idle time. To improve this crucial factor, researchers have tried to optimize power consumption in every aspect of the mobile device. Power consumption can be optimized by disks, memory chips, CPU scheduling, applications and communication techniques (Stemm and Gauthier,1997).

In Forman and Zahorjan, Strategies for power saving have been investigated at the various protocol layers, and the techniques include:

- Physical layer
  - use of directional antenna
  - Controlling the transmission power with knowledge of neighborhood.
- Data-link layer
  - Avoid unnecessary retransmission
  - Avoid collision in channel access.
  - Turn radio off (sleep) when not transmitting or receiving

- Network layer
    - Consider route relaying load.
    - Consider battery life in route selection
    - Reduce frequency of sending control headers.
    - Efficient route reconfiguration techniques.
- Transport layer
    - Avoid repeated retransmission
    - Use power-efficient error control schemes.

What differentiates ad-hoc networks from traditional wireless networks is the absence of a centralized base station. In traditional wireless networks, nodes wishing to communicate with each other have to first contact the nearest base station, which forwards their requests to the base station closest to the destination node. All packets are routed through the path established by the base station. The base stations perform the tasks of tracking, routing and route maintenance. In ad-hoc networks, all these tasks are performed by the nodes themselves, in addition to their personal tasks. This causes additional drain on the batteries leading to a diminished lifetime. Power utilization can be optimized by employing routing algorithms that avoid nodes with low battery power ready while trying to minimize the total power consumed in transmitting a packet (Stojmenovic and Lin, 2001).

In (Gobrail et al, 2004) power-aware MAC layer categorized into three categories:

- The Reservation Based Power-Aware MAC: tries to avoid collisions in the MAC layer, since collisions may result in retransmissions, leading to unnecessary power consumption.
- The Switching off Power-Aware MAC: tries to minimize the idle energy consumption by forcing nodes to enter the sleep mode.
- Transmission Power Control: came about because the maximum power is consumed during the transmission mode. According to the path-loss radio propagation model there is a non-linear relation between the transmission power and the transmission distance. It is more energy conserving (considering only transmission energy) to send the data in a multi-hop fashion using relay nodes rather than sending it directly to the destination.

In WLANs, the nodes included within the coverage area of a certain host may send control messages that collide with the RTS/CTS frames transmitted by this node. The higher the number of collisions the lower the network throughput is and the higher energy is consumed resolving them. The situation might be worse in a multi-hop wireless ad-hoc network, because each message potentially encounters collisions at each hop. As a result, the total number of collisions increases and more channel bandwidth and energy are wasted (Gobrail et al, 2004).

1.6 Motivations and Objectives

To design routing protocols for ad-hoc networks, significant research efforts have been proposed. Most of these researches take the shortest-path with minimum hop count as the main route selection criterion. But they ignore many important link capacity properties. First, the average queue length and the queuing delay are different from node to node, which is a consequence of different traffic load at each mobile node. Second, the number of a node's neighbors and their traffic patterns are different, and the nodes that have more active neighbors may face an increase of collisions than other nodes. The shortest route may actually cause longer end-to-end delay even though the number of hops is minimal, if they include some of these heavy nodes. Load aware routings for ad-hoc networks which utilize the load information as the path selection metric for routing in MANET. Power aware routing protocols for ad-hoc network utilize the power information as the path selection metric for routing in MANET, which aims to save power consumption in the ad-hoc network (Xuemei et al,2007).

In a wireless network, nodes contention to the shared channel leads to access delay and collision at the MAC layer. None of the routing protocols that have been proposed for MANET, considered node contention information and power saving simultaneously.

In determining end-to-end delay, contention times can be more critical than the number of hop. Many routing protocols use contention information as route selection criterion as the number of contention nodes of a node, but none of them use contention window (cw) size in route selection procedure.

The medium contention information at each node gives an idea about the medium contention time and traffic load at the node. We can reduce the end-to-end delay, and distribute traffic evenly throughout the network by using the medium contention information in the route selection procedure (Kim, 2003). We also propose to use contention information (cw size) and the remaining power level as the main path selection criterion in the route selection procedure.

From the network lifetime point of view, the low energy nodes are the most important and most critical nodes. These nodes have used their energy either because they have a lot of data to send or because they are located in the confluence of many routes. Leaving these critical nodes to deplete their energy may cause a network partition and some sources might be unable to reach other destinations.

In our research we propose a routing protocol that uses contention information as a route selection criterion, while each node on this path must have remaining power level higher than the specific power threshold. Our research also aims to conserve the channel bandwidth and the energy consumption by decreasing the total number of collisions. In addition low energy nodes are considered during the route discovery procedure Utilizing AODV with the additional modification.

The objective of this thesis is to study the proposed AODVCP and its effective on the network performance obtained by AODV. We will study the impact of AODVCP on the average end-to-end delay, routing overhead, network life time and the overall network throughput. The result will be compared with the result of AODV.

1.7 Thesis organization

This thesis contains five chapters outlined as follows:

Chapter one: presents a brief introduction about wireless networks and their properties, Routing and Power consumption in MANET, it also highlights the main objectives of the study.

Chapter two: present the AODV routing protocol, DCF, and some common power and load routing protocols for ad-hoc network are also reviewed.

Chapter three: introduces the Proposed AODVCP.

Chapter four: presents detailed description of simulation environment and the results obtained from the simulation. Also an introduction about the GloMoSim network simulator is highlighted.

Chapter five, finally conclusion of the thesis with future works.

2. LITERATURE REVIEW

2. Literature Review

2.1 Introduction

This chapter sheds light over some related works to power and load aware routing protocols in MANET's. We start with an introduction to the Ad-hoc On demand Distance Vector (AODV) routing protocol and an introduction to media access control (MAC) protocol.

2.2 AODV Overview

The Ad-hoc On-Demand Distance Vector (AODV) routing protocol is designed for use in ad-hoc mobile networks. AODV is a reactive protocol: the routes are created only when they are needed. It uses traditional routing tables, one entry per destination, and sequence numbers to determine whether routing information is up-to-date and to prevent routing loops. An important feature of AODV is the maintenance of time-based states in each node: a routing entry not recently used is expired. In case of a route is broken the neighbors can be notified. Route discovery is based on query and reply cycles, and route information is stored in all intermediate nodes along the route in the form of route table entries. The following control packets are used: routing request message (RREQ) is broadcasted by a node requiring a route to another node, routing reply message (RREP) is unicasted back to the source of RREQ, and route error message (RERR) is sent to notify other nodes of the loss of the link. HELLO messages are used for detecting and monitoring links to neighbors (Perkins and Royer, 1999).

2.2.1 Routing tables

Each routing table entry contains the following information:

- Destination
- Next hop
- Number of hops
- Destination sequence number
- Active neighbors for this route
- Expiration time for this route table entry.

Expiration time, also called lifetime, is reset each time the route has been used. The new expiration time is the sum of the current time and a parameter called active route timeout (Perkins and Royer, 1999).

2.2.2 Control messages

- **Routing request**

When a route is not available for the destination, a route request packet (RREQ) is flooded throughout the network. The RREQ contains the following:

Source address	Request DI	Destination address	Source Sequence#	Destination Sequence#	Hop count

Figure 2.1: Format of a ROUTE REQUEST Packet

The request ID is incremented each time the source node sends a new RREQ, so the pair (source address, request ID) identifies a RREQ uniquely. On receiving a RREQ message each node checks the source address and the request ID. If the node has already received a RREQ with the same pair of parameters the new RREQ packet will be discarded. Otherwise the RREQ will be either forwarded (broadcast) or replied (unicast) with a RREP message:

• if the node has no route entry for the destination, or it has one but this is no more an up-to-date route, the RREQ will be rebroadcasted with incremented hop count.

• if the node has a route with a sequence number greater than or equal to that of RREQ, a RREP message will be generated and sent back to the source. The number of RREQ messages that a node can send per second is limited. There is an optimization of AODV using an expanding ring (ESR) technique when flooding RREQ messages. Every RREQ carries a time to live (TTL) value that specifies the number of times this message should be re-broadcasted. This value is set to a predefined value at the first transmission and increased at retransmissions. Retransmissions occur if no replies are received. Historically such flooding used a TTL large enough, larger than the diameter of the network, to reach all nodes in the network, and so to guarantee successful route discovery in only one round of flooding. However, this low delay time approach causes high overhead and unnecessary broadcast messages (Perkins and Royer, 1999).

- **Routing reply**

If a node is the destination, or has a valid route to the destination, it unicasts a route reply message (RREP) back to the source. This message has the following format:

Source address	Destination address	Destination Sequence#	Hop count	Life time

Figure 2.2: Format of a ROUTE REPLY Packet

The reason one can unicast RREP back is that every node forwarding a RREQ message caches a route back to the source node (Perkins and Royer, 1999).

- **Route error**

All nodes monitor their own neighborhoods. When a node in an active route gets lost, a route error message (RERR) is generated to notify the other nodes on both sides of the link of the loss of this link (Perkins and Royer, 1999).

- **HELLO messages**

Each node can get to know its neighborhoods by using local broadcasts, so-called HELLO messages. Nodes neighbors are all the nodes that it can directly communicate with. Although AODV is a reactive protocol it uses these periodic HELLO messages to inform the neighbors that the link is still alive. The HELLO messages will never be forwarded because they are broadcasted with TTL = 1. When a node receives a HELLO message it refreshes the corresponding lifetime of the neighbor's information in the routing table. This local connectivity management should be distinguished from general topology management to optimize response time to local changes in the network (Perkins and Royer, 1999).

2.3 Media Access Control (MAC) protocol Overview

In the 802.11 protocol, the fundamental mechanism to access the medium is called Distributed Coordination Function (DCF). This is a random access scheme, based on the Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) protocol. Retransmission of collided packets is managed according to binary exponential bakeoff rules. When a node wants to send packets to another node, it first sends a Request To Send packet (RTS) to the destination after sensing the medium to be idle for a so-called DIFS interval. When the destination receives an RTS frame, it transmits a Clear To Send frame (CTS) immediately after sensing an idle channel for a so-called SIFS interval. The source transmits its data frame only if it receives the CTS correctly. If not, it is assumed that a collision occurred and an RTS retransmission is scheduled. After the data frame is received by the destination, it sends back an acknowledgment frame (IEEE 802.11,1997).

Nodes overhearing RTS, CTS, data or ACK packets have to defer their access to the medium. Each host maintains a Network Allocation Vector that records the duration of time during which it must defer its transmission. Figure 2.3 illustrates the operation of the IEEE 802.11 DCF (IEEE 802.11,1997).

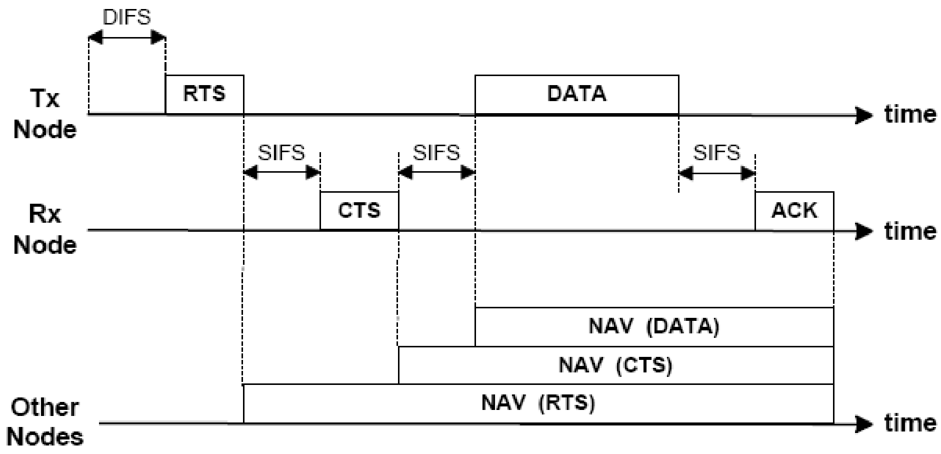

Figure 2.3: IEEE 802.11 DCF Operation

A collision occurs when two or more stations within the same transmission range of each other transmitted simultaneously in the same time slot. As a result, the transmitted packet is corrupted and the colliding hosts have to schedule a retransmission after deferring for a period randomly chosen in the interval [0..(CW-1)] where CW is the current value of the contention window of the node (IEEE 802.11,1997).

CW value depends on the number of failed transmission of a frame. The CW parameter shall take an initial value of CWmin. It shall take the next value every time of unsuccessful attempt of transmission until reaching the value of CW max. The CW shall remain at the value of CWmax until it will be reset. This improves the stability of the system in the case of heavy load. CW shall be reset to CWmin after every successful attempt of transmission. The set of CW values shall be sequentially ascending, integer powers of 2, minus 1, beginning with a CWmin and Continuing up to CWmax value. Figure 2.4 illustrates the increase of the contention window size using an exponential backoff mechanism. (IEEE 802.11, 1997).

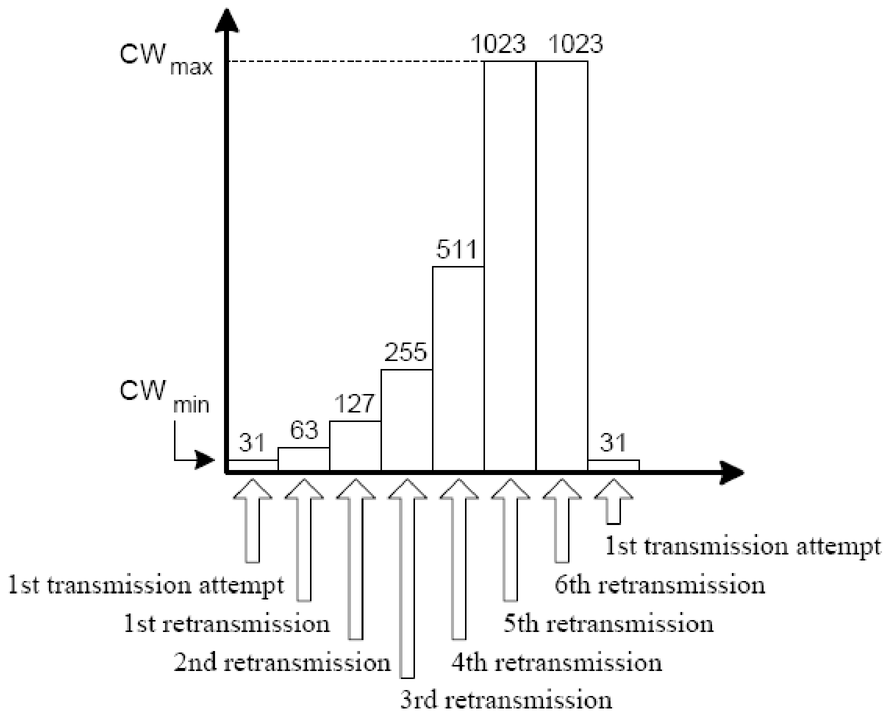

Figure 2.4: Exponential Increase of the CW

2.4 Load aware routing protocols

There has been a great deal of research on routing protocols over ad-hoc network. Load aware routing protocols utilize the load information as the route selection metric for routing in MANET, to reduce the chance of using the over utilized nodes while selection a path. Most of these protocols use the queue size as the main traffic loads metric on other hand the studies that use contention information as path selection are very limited (kim et al, 2003).

S.T. Sheu and J. Chen, proposed the Delay-Oriented Shortest Path Routing (DOSPR) protocol. This routing protocol uses the medium contention time information as the main criterion in the route selection procedure. In reality, the range of contention of a node covers not only its neighbors but also the neighbors of its neighbors; the DOSPR did not take this fact into account and limited the range of contention of a mobile node to its neighbors only. DOSPR did not consider load balancing and employed a table-driven approach rather than an on-demand one. Simulation results show that the derived path length in DOSPR is slightly higher than that of conventional shortest path with minimum hops approach but it can significantly reduce both average transfer delay and packet loss rate (Sheu and Chen,2001).

An ad-hoc routing protocol with Minimum Contention Time and Load Balancing (MCL) have been proposed in (Crow et al, 1997). MCL had two main characteristics. The first one is in the route selection procedure MCL selects a route with minimum contention. The second one is to prevent traffic from concentrating on a few nodes and to reduce the routing overhead; an intermediate nodes did not reply to route request in the route discovery procedure even though it know the path to the destination. Simulation results show that MCL outperforms AODV in term of packet delivery ratio, average end-to-end delay, and normalized routing overhead.

CQR is a Contention and Queue aware routing protocol based on DSR (Xuemei et al,2007), CQR use two load metrics for route selection. First, MAC layer channel contention information, which provides an accurate estimation of neighbor nodes' state. Second, the number of packets in the interface queue, which provides a measurement of traffic load at the mobile node itself. This load-aware routing protocol can effectively balance the load and improve the performance of the ad-hoc network. In Contention and Queue aware Routing protocol (CQR) the local laod at each node can be calculated using the following equations:

$$CW = \alpha * CW_{old} + (1-\alpha) * CW_{sample} \quad \ldots\ldots(2.1)$$

Where CW denotes the average contention window and CW_{sample} denotes the current contention window and α is constant and set to 0.3.

$$qlen = \beta * qlen_{old} + (1-\beta) * qlen_{sample} \quad \ldots\ldots(2.2)$$

Where qlen denotes the average queue length and $qlen_{sample}$ denotes the current queue length and β is constant and set to 0.3

$$Li = \mu * CW/CW_{max} + (1-\mu) * qlen / qlen_{max} \quad \ldots\ldots(2.3)$$

Where μ is set to 0.5 to balance the effect of the two factors which grants the same priority to the two factors. The small qlen mean the low load, the small CW reflects the benign channel and these cause lower Li. Simulation results show that CQR outperforms DSR in term of packet delivery ratio, average end-to-end delay, average end-to-end throughput and network life time.

Lee and Gerla proposed a Dynamic Load Aware Routing protocol (DLAR). DLAR defined the number of packets in the node's interface queue as the network load of a mobile node (lee and Gerla, 2001).

The Load Balanced Ad-hoc Routing protocol (LBAR) is proposed in (Hasanein and Zhou, 2001) , in LBAR the network load in a node is defined as the total number of routes passing through the node and its neighbors.

K. Wu and I. Harms proposed a Load Sensitive Routing protocol (LSR) in which the network load in a node is defined as the summation of the number of packets being queued in interface of the mobile host and its neighboring host (Wu and Harms, 2001).

In (Song et al, 2003), the routing protocol that has been proposed is based on delay measurements. The node's load value is defined as the average packet transfer delay at this node. With this definition, the queuing, contention and transmission delays are all considered.

The Contention Sensitive Load aware routing protocol (CSLAR) is proposed in (Li and Man, 2004). CSLAR used Network Allocation Vector (NAV) to estimate the neighbor nodes activities, queue length to measure the traffic load at the node itself. In the standard of IEEE 802.11, RTS/CTS packets have a field to specify how long the expected data packet will occupy the channel. When the neighbor nodes receive the RTS or CTS, they will set their NAV and defer any possible transmission to a later time. The NAV indicates the busyness of the medium. However, the value of NAV can not reflect the collision in the channel.

2.5 Power aware routing protocol

Power aware routing is an essential aspect in developing efficient routing techniques for mobile ad-hoc network. These types of techniques are required as most of the participating devices generally operate on low battery power. There is much effort has been done to deliver a routing solution which can not only route packet between two hosts in a mobile ad-hoc network but also consume less power (Gobrail et al, 2004).

On-demand protocols establish a routing path only when a transmission is required. In other words, if node A wants to transmit some information to node B, node A initiates a route discovery procedure. Once the route is found, data is transferred from A to B. Clearly, this approach is good, especially in terms of power saving. Moreover, some of these protocols allow nodes to go into sleep mode while they are not in an active transmission (Gobrail et al, 2004).

Many routing protocols have been proposed for MANET in order to achieve energy conversation. Thos protocols use different approach in order to save energy in MANET.

In Chang and Tassiulus, the optimal routing path is selected based on the minimum sum of link cost between a source-destination pair. The link cost is derived based on the initial and the residual battery energy of a mobile node (Change and Tassiulus, 2000).

In (Doshi et al, 2001) , minimum energy routing protocol have been proposed, the minimum energy protocol is based on the fact that a mobile node should transmit packet at a power level which should be just enough to reach the next hop. The source route contains information about minimum transmit power between the links. If each data packet carries power information in addition to source routing information, the packet size will increase. Those large packets need large time for transmission. Hence occupy more bandwidth. That is why including link by link power information in each data packet may not be a good choice in source routing protocol like DSR.

Smallest Common Power protocol (COMPOW) selects the smallest power level which is just enough to maintain connectivity to the entire network. Each node selects different power levels and build routing tables for each power level by exchanging that routing information among themselves, mobile nodes decide about the mammal power level that ensures connectivity to the entire network. But that kind of routing information exchange can cause excessive routing overhead in the network, which can affect the performance of the network (Narayanaswamy et al,2002).

In (Woo et al,2001), a Localized Energy Aware Routing protocol (LEAR) has been proposed mobile node decides to whether to forward or not to forward traffic for other depending upon the residual battery energy. If the residual battery energy is greater than a threshold, a mobile node forwards the traffic for other. The DSR has been modified in order to implement LEAR protocol.

Conditional Max-Min Battery capacity Routing (CMMBR) proposed in (Toh, 2001), it is similar to that of LEAR protocol. If all nodes in some possible path between a source-destination pair have larger remaining battery energy than the threshold, the min-power routes a among the discovered routes are selected. If all possible rotes have nodes with lower battery energy than the threshold, the max-min route is selected.

Several experiments have been done to compare different power aware routing protocols in terms of the network lifetime. The result showed that the first node in "Shortest Path routing" metric died sooner than all the power aware routing but most of the other nodes had longer expiration time.

3. CONTENTION AND POWER AWARE AD-HOC ON DEMAND DISTANCE VECTORE (AODVCP)

3. Contention and Power Aware Ad-hoc On Demand Distance Vector (AODVCP)

AODVCP is proposed as a modification to the AODV (perkins and royer, 1999). AODVCP uses the contention information as a route selection criterion, while each node on the selected path must have remaining power level higher than the specific power threshold. The CW indicates the busyness of the medium and can be considered as a useful metric for contention and traffic situation around the node. In other words, by calculating the average contention of the channel around a mobile node, the traffic load around the node can be estimated.

AODVCP has two main characteristics. Firstly, AODVCP selects a route with the minimum contention among many possible routes between source and destination in the route selection procedure but each node with this route should have remaining power more than the specific threshold. Secondly, intermediate nodes do not reply to RREQs in the route discovery procedure. These characteristics distribute traffic throughout the network and reduce the routing overhead.

The low energy nodes are the most important and the most critical nodes and leaving these critical nodes to deplete their energy may cause a network partition and some sources might be unable to reach other destinations.

AODVCP proposes a new strategy so that the nodes are probabilistically split into virtual groups according to the amount of residual battery energy remaining and to avoid the low energy node from entering in the route.

3.1 AODVCP

AODV modifies the ROUTE REQUEST (RREQ) and ROUTE REPLY (RREP) packets used in AODV by adding two additional fields: the average contention window field (CW) and remaining power field (POWER). Figures 3.1 and 3.2 show the new RREQ and RREP packets used in AODV respectively. When a source node has a packet to send and there is no available route to the destination in its route cache, a route request packet is initiated and flooded through the network. Each node receiving this request will process and forward it until it reaches its destination.

Source address	Request ID	Destination Address	Source Sequence#	Destination Sequence#	Hop count	CW	POWER

Figures 3.1: Format of a ROUTE REQUEST Packet

Source address	Destination address	Destination Sequence#	Hop count	Life time	CW	POWER

Figures 3.2: Format of a ROUTE REPLY Packet

When a ROUTE REQUEST Packet (RREQ) arrives to a node it proceeds in the following steps:

1- each node receive RREQ checks the source address field and the request id field inorder to reject the duplicated request by looking up in a local history table, so the processing is stopped when duplication exists or enter the request to the seen table if it is not duplicated.

2- If the receiver is intermediate node and its remaining power level is more than 30%, it will do the following:

- Compute its average contention window by applying the exponential weighted moving average method to the CWold and CWsample to calculate CW, as follow,

  $CW= \alpha * CWold + (1- \alpha)* CWsample$ ……………………………………….(3.1)

To better reflect the current condition of a node, α is set to 0.3, this grants a higher priority to the current CW. if the intermediate node has CW value more than the CW value in the RREQ, it replaces the value of this field by its CW (Xuemei et al,2007).

  - If the remaining power level is less than the power value in the RREQ it replaces the value of this field by its POWER.

If the receiver has power less than 30%, it discards the RREQ which prevents any node with remaining power less than the threshold from participating in the route. By doing this, the node will conserve its power and use it for its transmission only, and will not be a member in any route.

During the rout discovery process, the intermediate nodes are not allowed to send back RREP even if they have routes to the destination in their caches. The purpose is to get the up to date contention and load information along the whole route for each route discovery.

3- Once the RREQ reaches the destination, the destination generates a RREP and sends it back to the source node. When multiple routes are available, route selection is based on the value of the CW and POWER in the RREP.

4- Intermediate nodes relay the RREP if and only if it has power more than the threshold which equals 30%. Intermediate node update the route table entry for the destination if the incoming RREP has a CW value less than the pervious CW for this destination but if they are equal, it depends on the POWER value and updates the route table entry if the POWER value in the RREP is more than the previous POWER value.

Finally, the source node will use the route with minimum load and each node in the path with power higher than or equal 30%. When some link on an active route is broken, the source node is notified by a route error packet. The source updates its route cache by removing any route using this broken link, and then initiates another RREQ to find a new least load route if it is necessary.

4. Results and Analysis

4. Results and Analysis

4.1 Introduction

This chapter presents an overview of the simulator used in the experiments, simulation results and their analysis that will follow. Global Mobile Information System Simulation Library network simulator (GloMoSim) is used to evaluate the performance of the AODVCP (Gerla et al., 1999). The results show how the throughput, average end to end delay, discovery overhead and network life time are affected by varying traffic load in a specific amount of time.

4.2 What is GloMoSim?

Global Mobile Information System Simulator (GloMoSim) is a scalable simulation environment for large wireless and wired communication networks. GloMoSim uses a parallel discrete-event simulation capability provided by Parsec .It is designed in a layered approach with standard APIs used between the different simulation layers. The protocol stack includes models for the channel, radio, MAC, network, transport and higher layers (Gerla et al., 1999).

The GloMoSim kernel APIs are in the form of function calls, while for the other layers, the API is in the form of message exchanges required to interact with the layers. The following list the GloMoSim models which are currently available at each of the major layers:

- Physical or Radio Propagation layer: Free space and Two-Ray.
- Data Link layer (Mac): CSMA, MACA, TSMA , 802.11.
- Network layer: AODV, DSR,OSPF, LAR,WRP, FISHEYE, ZRP.
- Transport layer: TCP, UDP.
- Application layer: Telnet, FTP, CBR (Gerla et al., 1999).

4.3 Power Consumption model

In the GloMoSim simulator, the energy consumption model is implemented in the physical layer. There are four radio models implemented and supported by the simulator according to (Chaudhuri and Johnson, 2002).

- Transmit mode: The mode in which a node transmits a packet.
- Receive mode: The mode in which a node is receiving a packet.
- Idle mode: A node is neither transmitting nor receiving a packet, but it is listening to the wireless medium continuously in order to detect a packet that it should receive.
- Sleep mode: Nodes in this mode have very low power consumption since they are unable to transmit or receive packets.

The GloMoSim does not support the “Sleep” mode that corresponds to the low power energy mode where the radio cannot transmit or receive. The Sleep mode is not supported in the GloMoSim because monitoring the channel is assumed to consume power as much as the power consumed when receiving signals, thus the radio mode is either transmission (TX) or receiving (RX) in Ad-hoc networks. The following equation is used to calculate the consumption power during the transmission

TX= txDuration* (BATTERY_TX_POWER_COEFFICIENT * txPower +BATTERY_TX_POWER_OFFSET)(4.1)

Where: BATTERY_TX_POWER_COEFFICIENT=16/sec

BATTERY_TX_POWER_OFFSET= 900 mw.

txDuration is transmission time and txPower proportional to the distance that the signal traveled (Margi and Obraczka, 2004).

At the end of simulation, simulation time is multiplied by the cost of being in RX mode and then it is added to the energy consumption statistics. In order to compute the current battery level we give each node an initial power value and compute the percentage of battery level.

4.4 Simulation Environment

Simulations are conducted on the GloMoSim. At MAC layer, the DCF of IEEE 802.11 standard for wireless LANs is used. The radio model is based on Two-Ray ground reflection model. The mobility is modeled as the random waypoint model in a square field with a dimension of 2000 * 2000 meter.

Each node moves independently with a 25 m/sc as maximum mobility speed and 15 second as pause time. The simulation traffic is a Constant Bit Rate (CBR). In order to use CBR, the following format is needed:

CBR <src> <dest> <items to send> <item size> <interval> <start time> <end time>

Where:

<src> the client node.

<dest> the server node.

<items to send> how many application layer items to send.

<item size> size of each application layer item.

<interval> the interdeparture time between the application layer items.

<start time> when to start CBR during the simulation.

<end time> when to terminate CBR during the simulation.

In our experiments, the size of application data was 512 bytes with 10 traffic sources. Simulations are run for 500 seconds. All data points are calculated as an average of 10 runs with different mobility scenarios. The following table shows some of our simulation environment.

Table 4.1: Simulation environment

Simulation time	500 second
Terrain dimension	2000*2000 m
Mobility-WP-Pause	15sc
Mobility-WP-Max-Speed	25m/sec
Number of Connections	10
Size of item	512byte
Interval	5 sec
Number of Experiments	10

4.5 Performance Metrics

Four metrics are used to test the performance of the networks and to compare between the two protocols AODV and AODVCP.

- End-to-end delay: the average end-to-end delay is the average of delays for all received packets from the source to the destination.
- Network life time: Lifetime of the network is the time taken for the battery of the first node to be drained off in the network. The number of critical nodes, node with battery level equal or less than 5%, give us an idea about the network life time.
- Routing Overhead: is the average number of control packets transmitted at each node during the simulation.
- End-to-end throughput is calculated as received throughput in bit/sec received at the traffic destination.

4.6 Results and Analysis

Two protocols are simulated: AODV and AODVCP. Figures 4.1-4.8 highlight the relative performance of the two protocols. Our protocol outperforms the other routing protocol with higher throughput, less end-to-end delay, less discovery overhead and longer network lifetime. The traffic load and the collisions are used as performance parameters.

4.6.1 Different number of packets

By increasing the number of packets we can change the traffic load of the network. Each traffic source has to send 20,40,60,80 and 100 packets in a network of 100 mobile nodes.

Figure 4.1 compares between the AODV and AODVCP according to the average End-to-end delay while changing the traffic load. The average End-to-end delay of AODVCP is better than that of AODV regardless of the traffic load. The reason is that AODVCP uses the average contention window (CW) as a rout selection criterion. Because AODV transmits data packets over a route with minimum contention, it has lower contention time than AODV, which does not consider contention time that occurs in the medium reservation procedure. This will reduce packet delay. Contention time can be more critical than hop count in determining the end-to-end delay. Another reason is that, due to load balancing, AODVCP has lower queuing delay than AODV, which does not take load balancing into account. This will also reduce packet delay. The improvement ratio of average end-to-end delay gained by AODVCP is 63.69%

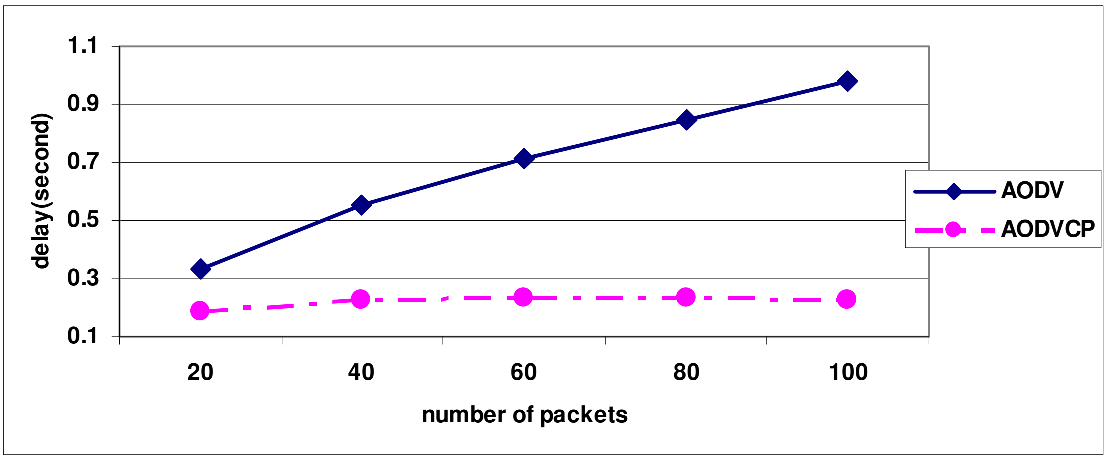

Figure 4.1: Average End-to-end delay Vs. Number of Packets

In Figure 4.2, we show the end-to-end throughput. AODVCP has higher throughput in average than AODV. High level of network congestion and access interference exist in certain region. Because AODV has not any load balancing mechanism, some routes may be included in the congested node and lead to more losses. AODV can not reflect the contention of the channel and there may be much collisions, AODVCP outperform it in end-to-end throughput. AODVCP shows declining in its throughput values with varying traffic load and this is primarily due to the increase of the collisions and losses when the traffic load increases.. The improvement ratio of average end-to-end throughput gained by AODVCP is 24.025%.

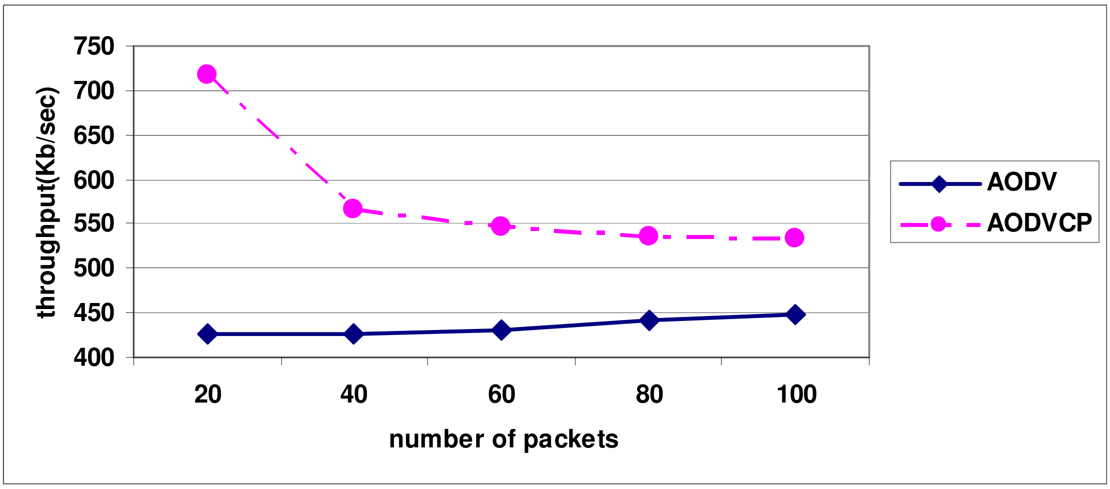

Figure 4.2: Average End-to-end throughput Vs. Number of Packets

Figure 4.3 illustrates the number of critical nodes with varying traffic loads in a dynamic network environment. The critical nodes are the nodes with battery level less than or equal 5%, these nodes give us an idea about the network life time and the power consumption. AODVCP outperform AODV in term of network life time as the traffic load increasing. Balancing the load of the network, protecting some busy nodes, and preventing any node with remaining power less than 30% from participating in routing allow these nodes to conserve its power and use it only for its transmission. In other words, AODV extends the network life time and conserves the power by avoiding the low energy nodes and decreasing the total number of collisions in the MAC layer. Since collision may result in retransmissions, leading to unnecessary power consumption. The improvement ratio of critical nodes reduction gained by AODVCP is calculated to be 78.94%.

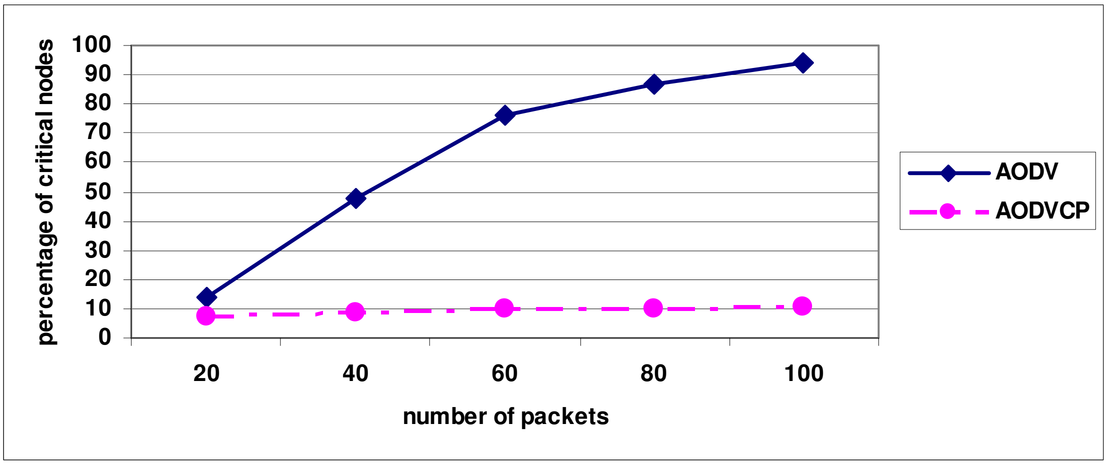

Figure 4.3: Percentage of critical nodes Vs. Number of Packets

In Figure 4.4, we show the routing overhead of the two protocols as the traffic load increases. AODVCP outperform AODV. AODVCP reduces the average number of control packets transmitted. AODVCP does not allow the intermediate node to send back route replies even if they have route to the destination in its caches, so the number of RREP in AODV is more than that of AODVCP. The improvement ratio of Routing Overhead reduction gained by AODVCP is 29.23%.

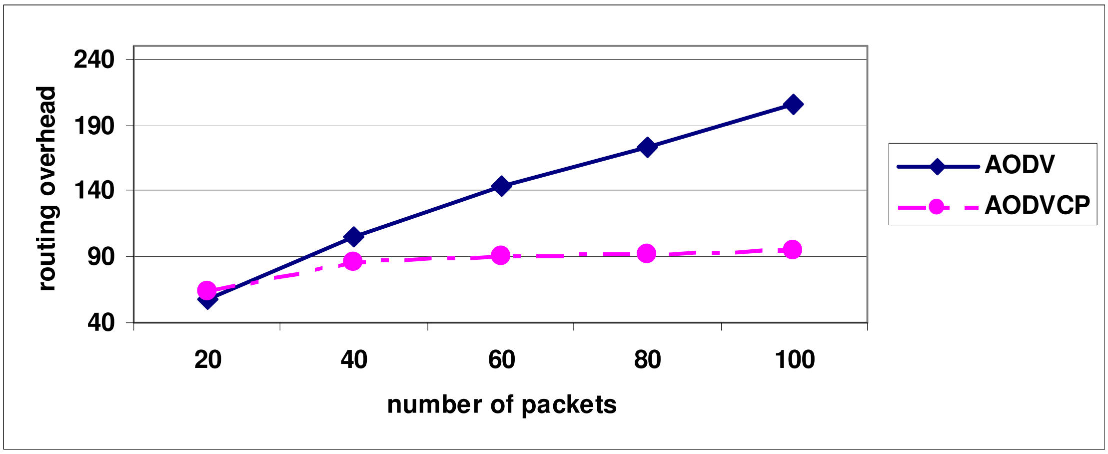

Figure 4.4: Average of Routing Overhead vs. Number of Packets

4.6.2 Different number of nodes

In this section, a comparison is given between the two protocols, AODV and AODVCP according to the number of mobile nodes which participates in the network. As we increase the number of nodes in the network, the load and collision will be increased. Each traffic source has to send 100 packets in a network of 20,40,60,80 and 100 mobile nodes.

Figure 4.5 compares between the AODV and AODVCP according to Average end-to-end delay while changing the number of nodes. AODVCP uses the route with minimum contention which reduces the packet delay, also due to load balancing; AODVCP has lower queuing delay than AODV. The improvement ratio of average end-to-end delay gained by AODVCP is 71.23%

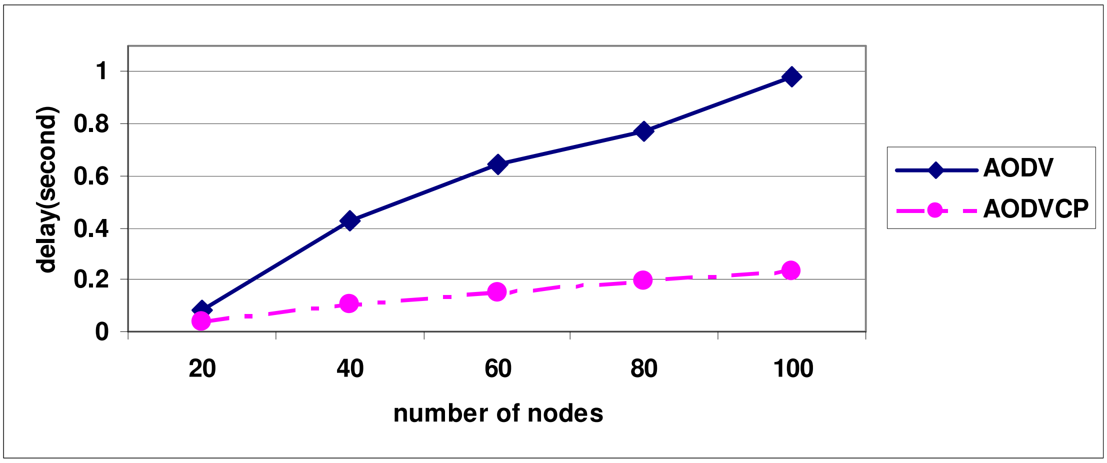

Figure 4.5: Average End-to-end delay vs. Number of Nodes

In Figure 4.6, we show the end-to-end throughput. AODVCP has a higher throughput in average than AODV. AODVCP uses the relatively less load node and balancing the load of the network and this minimizes the collision and losses. AODVCP shows declining in its throughput values with varying number of nodes. This is due to the increase in the collisions and the losses when the number of nodes increases. The improvement ratio of average end-to-end throughput gained by AODVCP is 22.11%.

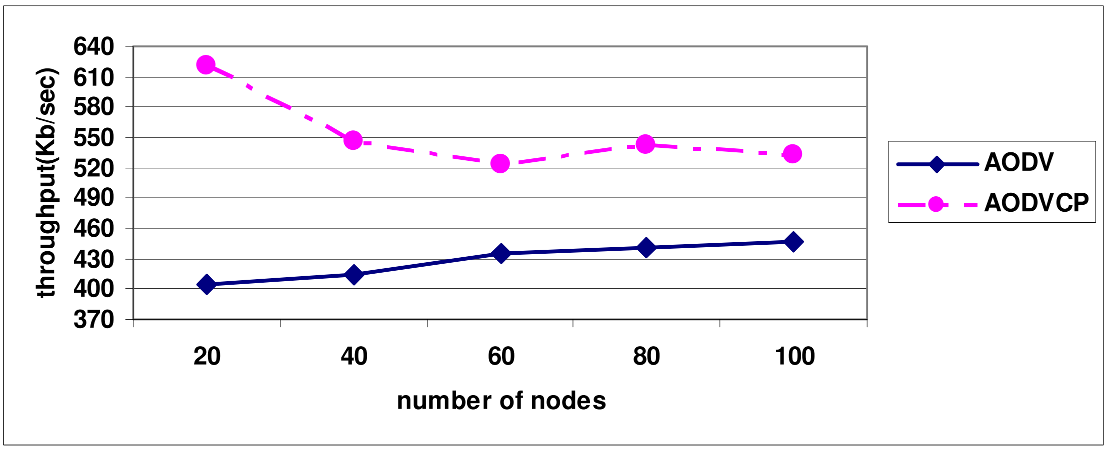

Figure 4.6: Average End-to-end throughput vs. Number of Nodes

Figure 4.7 illustrates the number of critical nodes with varying number of nodes in a dynamic network environment. AODVCP outperform AODV .We use the relatively less load node and that has less contention node, thus avoiding hot node, balancing the load of the network, and protect some busy nodes. As a result, AODVCP lengthens the life time of the network and decrease the power consumption. The improvement ratio of critical nodes reduction gained by AODVCP amounts to 78.84%.

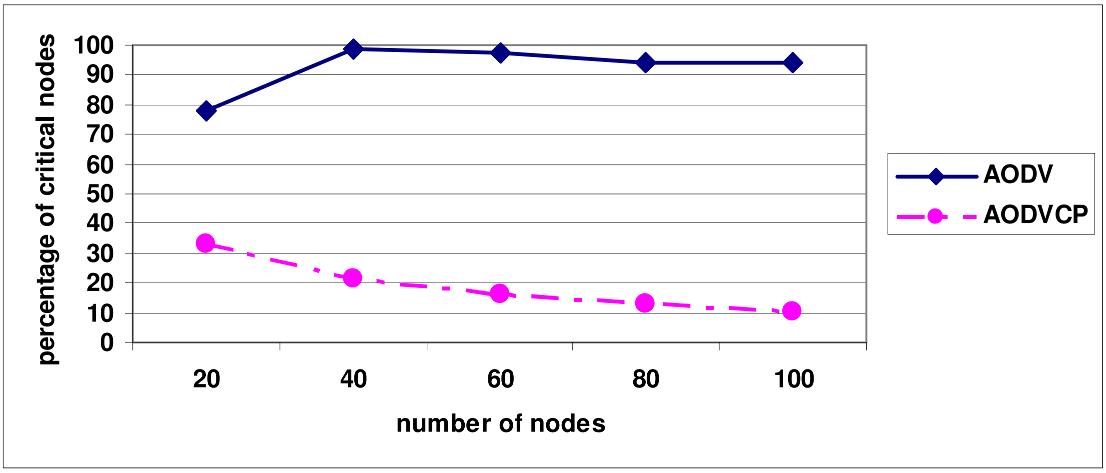

Figure 4.7: Percentage of critical nodes vs. Number of Nodes

In Figure 4.8, we show the Routing Overhead of the two protocols as the number of nodes increases. AODVCP outperforms AODV. In AODVCP, we are preventing intermediate nodes from initiating RREP if they know the path to the destination which reduce the number of RREP. In AODV the number of its RREP is more than that of AODVCP. The improvement ratio of Routing Overhead reduction gained by AODVCP is 53.33%.

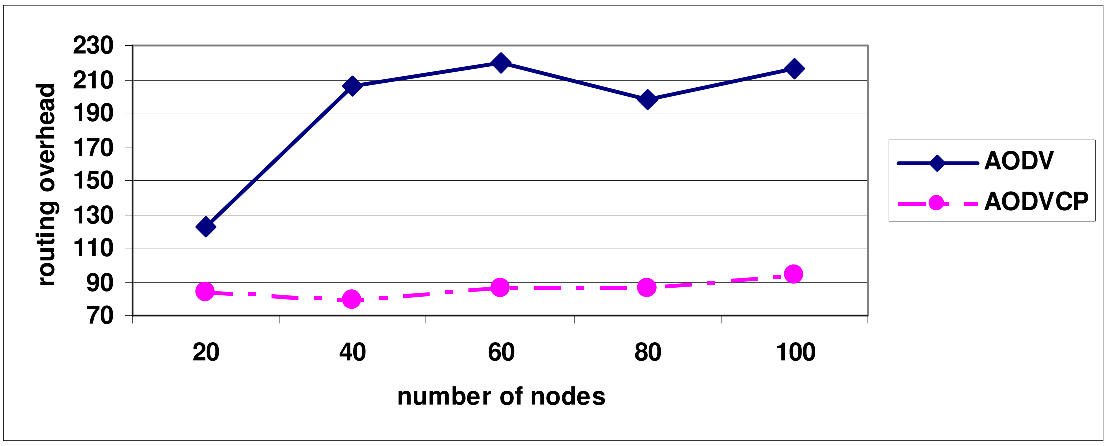

Figure 4.8: Average of Routing Overhead vs. Number of Nodes

4.7 Power Threshold (TH)

In this section we explain why we choose specifically 30% to be the power threshold (TH), i.e., not more or less. The traffic load is used as a performance parameter. Routing overhead and the number of critical nodes is used as performance metric.

Figures 4.9 and 4.10 show the average routing overhead for the AODVCP with different power thresholds, 30% and 50%. 30% outperforms 50% in term of routing overhead; when TH set to 50% the Routing Overhead will be increased because in AODVCP only the node with the remaining power level more than 50% can participate in the path. This in turn increases the number of nodes that are prevented from participating in the route and increase the RREQ discarding, thus, the route overhead will be increased. The improvement ratio of Routing Overhead reduction gained by TH=30% touches 31.61% for the different number of packets and 25.68% for different number of nodes.

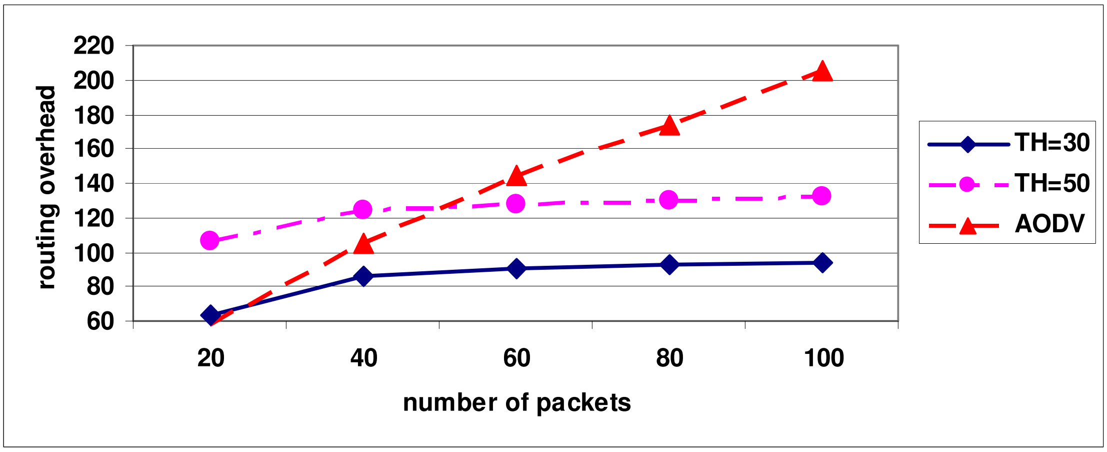

Figure 4.9: Average of Routing Overhead vs. Number of Packets

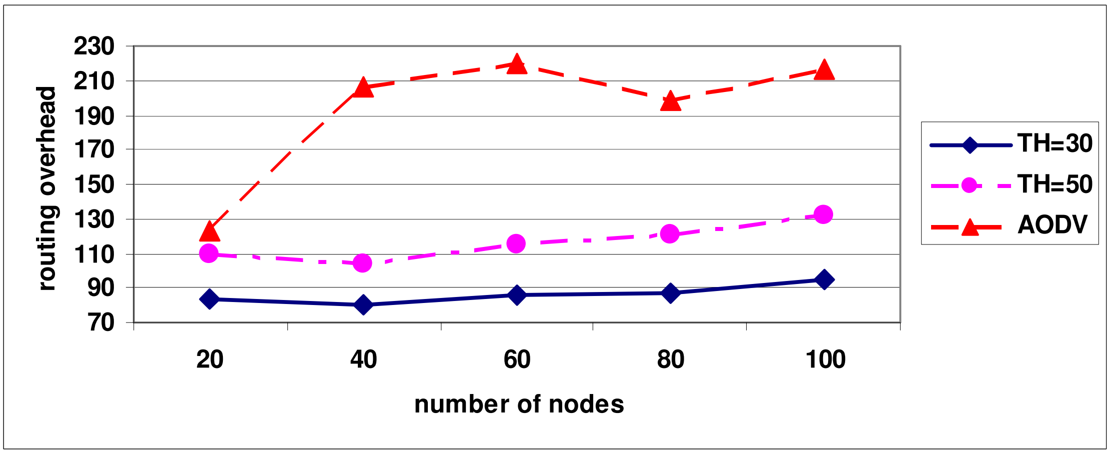

Figure 4.10: Average of Routing Overhead vs. Number of Nodes

Figures 4.11 and 4.12 represent the number of critical nodes at AODVCP with 10% and 30% as the power threshold. It can be seen that when TH is set to 30%, the number of critical nodes will be minimized, and this extends the network life time. Small power threshold value allows the node with small battery level to participate in the route which increases the power consumption at these critical nodes and at the end enter the critical zone. The improvement ratio of Percentage of critical nodes reduction gained by

TH=30% reaches 81.61% for the different number of packets and 73.83% for different number of nodes.

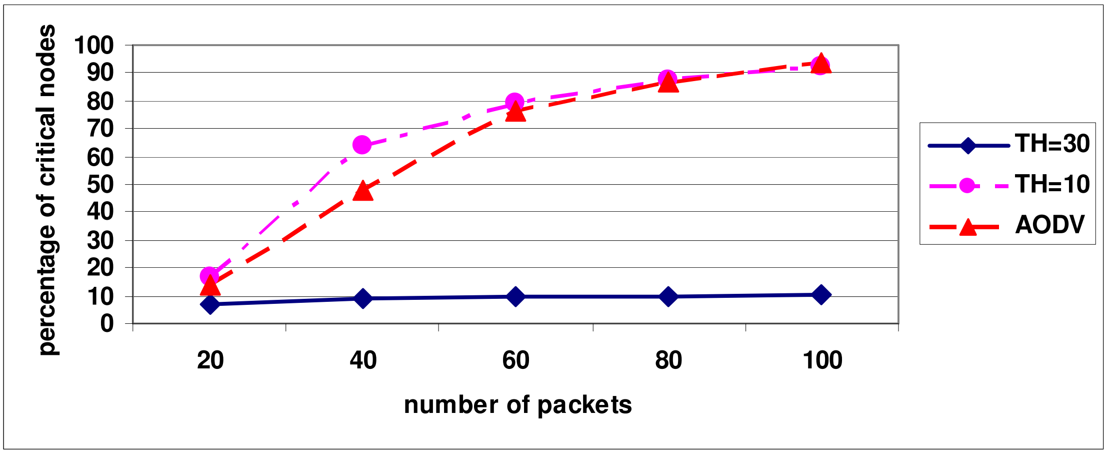

Figure 4.11: Percentage of critical nodes Vs. Number of Packets

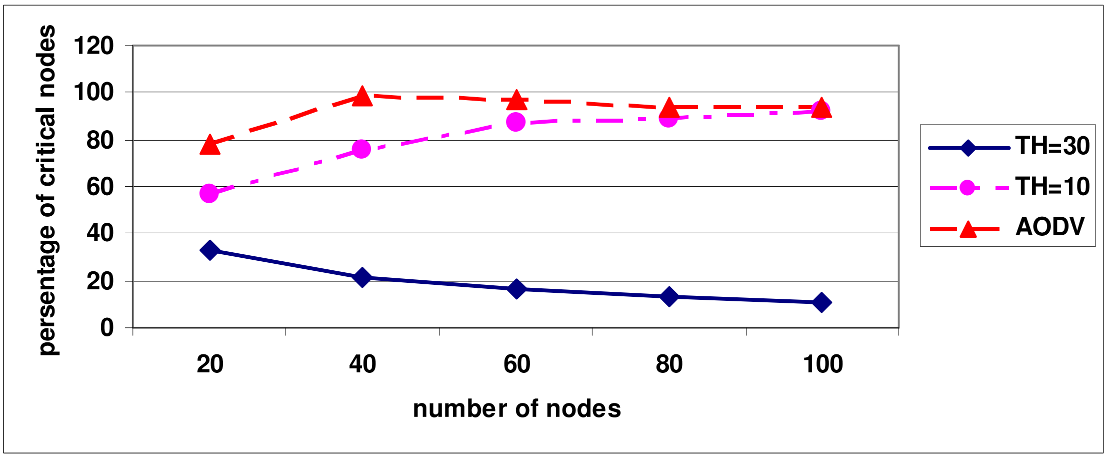

Figure 4.12: Percentage of critical nodes Vs. Number of Nodes

When we set the power threshold (TH) to a large value, 50% for example, we increase the Routing Overhead and extend the network life time, and when we set it to small value, 10% for example, we reduce the Routing Overhead with increasing the percentage of critical nodes which reduces the network life time. So, to reduce the discovery overhead and to extend the network life time at the same time, 30% is selected to be TH value.

5. CONCLUSIONS AND FUTURE WORKS

5. Conclusions and Future Works

5.1 Conclusion

In this thesis, we proposed an ad-hoc routing protocol (AODVCP) with a minimum contention time, load balancing and power aware. The AODVCP routing protocol considers medium contention time and remaining power level in the route selection procedure.

The performance parameters that we used were the traffic load and collisions by increasing the number of packets and the number of nodes. Different Performance metrics were used to compare between AODVCP and AODV, including the average end-to-end throughput, average end-to-end delay, discovery overhead and network life time.

Simulation results show that, in comparison to AODV, AODVCP yields better performance in terms of the average end-to-end throughput, average end-to-end delay, routing overhead as well as network life time.

The following tables summarize the improvement ratios that have been obtained from our protocol AODVCP, and the improvement ratios obtained by AODVCP with TH=30% regarding to our performance metrics and parameter. Table 5.1 shows the improvement ratios obtained by AODVCP regarding to the average end-to-end delay, the average end-to-end throughput, the routing overhead and the percentage of critical nodes.

Table 5.1: AODVCP Improvement Ratio

Performance Metric	IR(number of packets)	IR(number of nodes)
Average end-to-end delay	63.69%	71.23%
Average end-to-end throughput	24.02%	22.11%
Routing Overhead	29.23%	53.33%
Percentage of Critical Nodes	78.94%	78.84%

Table 5.2 shows the improvement ratios obtained by AODVCP with TH set to 30% regarding to the discovery overhead and the percentage of critical nodes. It is clear that AODVCP with TH set to 30% incurs less routing overhead and increases the network life time.

Table 5.2: TH=30% Improvement Ratio

Performance Metric	IR(number of packets)	IR(number of nodes)
Discovery Overhead	31.61%	25.68%
Percentage of Critical Nodes	81.68%	73.83%

5.2 Future Works:

In our study, we used the average contention window to give us an idea about the load and the traffic around the mobile nodes, but what about the load at the node itself, our future work will utilize other factors in addition to the contention window in computing the current and real load at each mobile node on the network. In the future, attempts will be made in order to find a formula that combines all traffic factors that can be used in calculating the current and real load at each mobile node.

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APPENDIX A: Results Summary

Table A.1: End to end throughput of AODV and AODVCP with 100 mobile nodes and different number of packets in 2000*2000 terrain dimension

packets	AODV	AODVCP
20	427.1324	716.9479
40	[illegible]	[illegible]

Table A.4: Percentage of critical nodes of AODV and AODVCP with 100 mobile nodes and different number of packets in 2000*2000 terrain dimension

packets	AODV	AODVCP
20	13.9	7.2
40	47.7	8.8
60	76.4	9.7
80	86.8	9.9
100	94	10.3

Table A.5: End to end throughput of AODV and AODVCP with 100 packets and different number of mobile nodes in 2000*2000 terrain dimension

nodes	AODV	AODVCP
20	405.0126	621.3874
40	413.3242	545.4739
60	435.169	522.8711
80	441.2275	542.0374
100	447.3945	533.3321

Table A.6: End to end delay of AODV and AODVCP with 100 packets and different number of mobile nodes in 2000*2000 terrain dimension

nodes	AODV	AODVCP
20	0.083444	0.039353
40	0.426256	0.104957
60	0.641642	0.149191
80	0.768377	0.195232
100	0.982771	0.229995

Table A.7: Routing overhead of AODV and AODVCP with 100 packets and different number of mobile nodes in 2000*2000 terrain dimension

nodes	AODV	AODVCP
20	122.43	83.87
40	206.145	79.7025
60	219.8117	85.92333
80	198.0738	86.3875
100	216.6439	94.226

Table A.8: Percentage of critical nodes of AODV and AODVCP with 100 packets and different number of mobile nodes in 2000*2000 terrain dimension

nodes	AODV	AODVCP
20	78	33
40	98.5	21.75
60	97.3333	16.1667
80	93.875	13
100	94	10.3

بروتوكول التوجيه المعتمد على التنافس والطاقة لشبكات التنقل العشوائي

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نسيبه مصطفى عبدالعزيز الطراونه
المشرف
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المشرف المشارك
الدكتور وسام المبيضين

ملخص

الشبكة اللاسلكية التي لا تعتمد على البنية التحتية هي عبارة عن مجموعه من محطات الحاسوب اللاسلكية المتحركة ديناميكيا والتي تشكل شبكة مؤقتة من دون استخدام أي من شبكات البنية التحتية أو الإداره المركزية. هنالك العديد من بروتوكولات التوجيه التي اقترحت لمحطات الحاسوب اللاسلكية ومعظمها لا يعتبر التنافس على الوقت المخصص لحجز قناة الإرسال. تخصيص وقت تنافس كبير يمكن أن يكون أكثر أهميه من عدد القفزات في تحديد وقت التأخير من بداية الإرسال إلى نهايته.

عند استخدام شبكات الحاسوب اللاسلكية التي لا تعتمد على البنية التحتية فإن حجم الإرسال لمحطات الحاسوب اللاسلكية المتحركة يمكن أن يؤدي إلى تأخير طويل نتيجة للاصطفاف وعدم كفاءة استهلاك الطاقة. في هذه الإطروحه إقترحنا بروتوكول توجيه لشبكات الحاسوب اللاسلكية التي لا تعتمد على البنية التحتية يدعى AODVCP. إن بروتوكول التوجيه المقترح AODVCPيختار المسار الذي يكون عليه اقل وقت تنافس من بين العديد من المسارات المحتملة بين المحطة المرسلة والمحطة المستقبلة. وأثناء عملية الاختيار للمسار فإن كل محطة لاسلكية معينه في المسار المتبع يجب أن تحافظ على قيمه معينه من الطاقة. AODVCP يساعد على توزيع حجم الإرسال والطاقة على جميع أطراف الشبكة.

في هذه الإطروحه قارنا بين بروتوكول التوجيه المقترح AODVCP مع بروتوكول التوجيـــه المعتمد على المسافة في محطات الحاسوب اللاسلكية التي لا تعتمد على البنية التحتيـــة AODV .نتائج المحاكاة أظهرت أن أداء بروتوكول التوجيه المقترح كان أفــضل مــن أداء بروتوكــول التوجيه المعتمد على المسافة من حيث معدل التأخير ومعدل الشغل المنجز بوحدة الــزمن ومــن حيث عبْ إيجاد الطريق وعمر الشبكة. كان معدل التحسين في أداء الشبكة 23%, وكانت نــسبة التحسن في تقليل التأخير 67% وكانت نسبة التحسن في عبْ إيجاد الطريق و عمر الشبكة 41% و % 78 على التوالي.