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Performance Evaluation of IPv4 and IPv6 Routing Protocols on Wired, Wireless and Hybrid Networks

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Abstract – A routing protocol is used to determine the optimal path to forward the packets from source to destination. A separate set of protocols is designed for IPv4 & IPv6 network such as RIP, OSPF-v2, RIPng, OSPF-v3, and AODV. IPv4 is replaced by IPv6 (next generation internet protocol), but both the protocols are not suitable for each other, due to this they need to coexist for a long time. In this paper, the performance is evaluated for different routing protocols for IPv4 and IPv6 over wired, wireless and the hybrid network. Simulations are carried out on EXata/Cyber 2.1 Simulator/Emulator. The performance of routing protocols is measured on the basis of throughput, jitter, end-to-end delay and packet delivery ratio (PDR). By the simulation, on the basis of throughput and PDR performance of AODV (IPv4) is very good as compared with other routing protocols. It has been observed that due to the size of the IPv6 header, which is larger than IPv4 header the performance of routing protocols downgrades.

Index Terms – Routing Protocols, RIP-v2, RIPng, OSPF-v2, OSPF-v3, AODV.

1. INTRODUCTION

One of the most widely used protocols over the internet is IP (Internet Protocol). IPv4 is the 32-bit addressing scheme and can address 2^{32} devices (4.3 billion addresses). As the use of the internet grows up IPv4 addresses will be decreased and a new addressing scheme is needed. Thus, IPv6 (next generation internet protocol) came into existence. IPv6 is the 128-bit addressing scheme and can address 2^{128} devices, which is a huge number as compared to IPv4 [1] [2]. As we know IPv6 takes the place of IPv4, but they are not compatible with each other, separate set of routing protocols is needed for both the networks. In this paper, the performance of these routing protocols in IPv4 and IPv6 over the wired, wireless and the hybrid network is tested. Due to the larger size of IPv6 header the performance of routing protocols is low as compared to IPv4. We also analyzed that routing protocols in the wireless network perform low as compared to wired and the hybrid network due to the reason that the transmission range of wireless network is low as compared to other. In [3], the authors suggested some packet loss probability in the wireless networks. These include: delay, router load, packet length, buffer size, traffic load, radio range etc.

For sending the packets from one node to another we can use wired, wireless and the hybrid network. A wired network is a network where nodes are connected through the cable. Wireless networks are classified into two types: Infrastructure-based and infrastructure less. When a node wants to communicate in infrastructure based networks, they first send the packets to the access point or base station, but in infrastructure less networks there is no need of base stations. Every node can communicate directly to each other. Infrastructure less networks are known as Ad-hoc networks. Mobile Ad Hoc Network is a collection of mobile nodes. Each node in MANET act as a router and they can move freely anywhere in the network. Nodes in MANET can join the network when they wish that is called the selfish behavior of the nodes. Selfish behavior of nodes increases the packet loss ratio, which on the other end affect the performance of the network. Cooperation of the nodes can overcome some challenges in MANET [4]. Sometimes we want to cover a larger area with less fixed infrastructure, less number of antenna and base station to reduce the overall power consumption. This leads a new network, which is a combination of ad hoc network and wired network with base stations. This network is termed as the hybrid network. Hybrid means a "mixture" of the wired and wireless network. In this network data flow takes place from mobile nodes with non-mobile nodes and vice-versa. The base station or access point act as a gateway between wired and the ad hoc networks [5].

In this research paper, we highlight the key features of routing protocols in wired, wireless and the hybrid networks. Next we compare the performance of these routing protocols on the basis of throughput, end-to-end delay, jitter and PDR. We have used EXata/Cyber 2.1 for simulations.

The rest of the paper is structured as follows: Section 2 describes Routing and different types of routing protocols, Section 3 outlines with the simulation setup used in this research. We present the results and discuss the performance

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metrics used in the study in Section 4 and finally, the results conclude in Section 6.

2. RELATED WORK

2.1. Routing

Routing protocols will play an important role in today's internet era. It is the process of forwarding packets from one node to another. Routing is performed by the device called routers. Two steps involved in routing are: forwarding packets and taking a decision to forward packets based on an optimum path. The router uses the routing table to find the routes between nodes in the network. With the help of routing tables, the router knows which path to follow to reach the destination. In a network, a node is either connected directly or by the sequence of nodes to the destination, then a node must find the way to the destination. Such a node can find the path information either by static routing or dynamic routing. In static routing, routing tables are updated manually or by the administrator. All the entries will remain the same unless they are changed manually, whereas in dynamic routing when there is a change in network topology, routing tables are updated automatically with the help of routing protocols.

In wireless network due to the mobility of nodes, the network topology is frequently changed, thus routing is a very challenging task in wireless network [6] [7] [8]. The routing protocols for ad hoc network can be divided into types: proactive and reactive. Proactive protocols are table driven they maintain a routing table in advance to find the routes for all source and destination pairs and exchange topology information periodically. On the other hand, reactive protocols also referred as on-demand routing protocols need not maintain the routing information. They find routes when there is a need for routes [9].

2.2. Routing Protocols

Our work primarily concerns the important routing protocols for Pv4 and IPv6 networks. In this section we briefly describe the main function of routing protocols.

2.2.1. Routing Information Protocol (RIP)

RIP is an intradomain routing protocol. Routing is performed within an autonomous system. It is based on distance vector routing and uses hop count as a metric. RIP enabled routers are sometimes active and passive. After 30s active routers send its routing table to others and listens any updates from the other ones, whereas passive routers doesn’t propagate its own routing table. Two types of messages are used by RIP: request and response. A request message is sent by a router when it comes up and response is sent only answer to the request. RIP sends regular routing updates when there is a change in network topology. It uses different types of timers such as periodic, expiration and garbage collection timers. Periodic timers are used periodically for advertising route update messages. Expiration timer is used for defining the validity of the route and garbage collection timer advertises route failure. The main feature of RIP enabled routers is sharing of routing tables with neighboring routers. RIP protocol performs well in small networks and provides network scalability. There are three versions of RIP: RIP v-1, RIP v-2 and RIPng (RIP for next generation). Key features of RIP are:

1. RIP uses hop count as metric to find the optimum path between source and destination.
2. It limits the size of network as 16 hops are considered as infinity.
3. It is a very simple protocol and easy to configure.
4. RIP supports load-balancing.

2.2.2. Open Shortest Path First (OSPF) Protocol

It is an intradomain routing protocol based on link state routing. It is a hierarchical routing protocol which is very useful for large networks. OSPF supports VLSM (variable length subnet mask) or CIDR (class inter domain routing) addressing modes [10]. It divides the autonomous system into the area. An area contains networks, hosts and routers. If there is a change in the network, OSPF enabled node immediately multicast the change to all other nodes so that they can update their routing tables. OSPF only sends the change part of the routing table to other nodes. A Router running this protocol dynamically learns routes from other routes and with the help of LSA (link state advertisement) advertise to other routes. There are three versions of OSPF: OSPF-v1, OSPF-v2 and OSPF-v3. Some of the key features of OSPF are:

1. OSPF performs routing for large networks.
2. During transmission of packets, less bandwidth is required.
3. In OSPF routing updates are sends immediately so provides fast convergence.
4. It supports hierarchical routing inside the autonomous system.

2.2.3. Ad Hoc On-Demand Distance Vector (AODV) Protocol

AODV came under the category of reactive routing protocol in which, when there is a need of path route is created. It is a source initiated algorithm where the routing path from the source to the destination is initiated only by the source. There are three types of messages involved in path detection methods: RREQ, RREP and REER. When the source node is not found any path in its routing table to the destination, it sends RREQ message to all its neighboring nodes. RREQ contains the source address, broadcast id; sequence no, destination sequence no. On receiving RREQ each neighboring node,

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checks destination id and after founding the path, The RREP is sent back to the requesting node. If the link is broken, REER is sent to the requesting node indicating that there is some error in the link [11]. AODV is highly scalable and supports unicast and multicast routing. Key features of AODV:

1. AODV discovers routes when needed.
2. AODV is flat routing protocol.
3. Routing in AODV is loop-free.
4. The freshness of the route is ensured by the sequence number.

3. SIMULATION SCENARIO & PERFORMANCE METRICES

Simulation plays a very important role in developing and testing the performance of the network. In order to check the performance of various routing protocols, simulations are carried out in EXata/Cyber 2.1 Simulator/Emulator [12].

3.1. Description of scenarios

3.1.1. Wired Scenario

The wired scenario is divided into three networks. Each network is connected with each other by routers. For storing the packets, a router uses the buffer and the size of the buffer is set to 150000.The switch is used as layer 2 device. If a node on one network wants to communicate with a node on another network, the packet is first sent to layer 2 device. It first checks into the same network and then forwards to the router. The router searches its routing table and sends the packets to the correct destination.

3.1.2. Wireless Scenario

In our wireless scenario, every node in the network act as a router for forwarding the packets. If a node is within the transmission range, node directly sends the packets, but if it is out of the transmission range, node relies on the intermediate node for forwarding the packets. The omnidirectional antenna model is used due to the fact that it works in all directions. Their radiation cone is 360 degrees in all directions. Simulation is carried out in 50 nodes using constant bit rate (CBR) as traffic. A number of packets sent by each node are 7500 with the size of 512 bytes.

3.1.3. Hybrid Scenario

Our mixed scenario consists of a wireless and a wired domain. The simulation was performed with 30 wireless nodes and 20 wired nodes. For our hybrid network environment, we have an access point located at the center of the simulation area. Every communication between wired and wireless nodes goes through the access point. The station association type is dynamic. The access point is connected to the hub (layer 2 device). If a node on wired network wants to send the packet to the wireless node, the packet is first sent to the access point. With the use of ad hoc routing protocol, the access point sends the packet to its correct destination. Similarly, the packets from wireless nodes send the packets towards their assigned access points and then the access point sends it to the wired domain.

We have done the simulation on 40 nodes using 4 CBR as traffic on a packet size of 512 bytes over wired, wireless and the hybrid network. Table1 summarizes the parameters which are selected to check the performance of routing protocols.

Table 1 Simulation Parameters

Parameter	**Value**
Simulator	Exata/Cyber 2.1
Simulation run Time(sec)	100
Studied Protocol	IPv4- RIPv2,OSPFv2,AODV IPv6- RIPng,OSPFv3,AODV
Simulation Area	1500m x 1500m
Network Type	Wired, Wireless, Hybrid
No of nodes	50
Packet size (bytes)	512
No. of packets from each source node	7500
Type of Application	Constant Bit Rate
No. of Application	04
Antenna model	Omni-directional
Traffic Rate	100 packets per second

In [13] author's emphasis on quality of service which means how the network provides good service in any kind of traffic. Quality defines loss of data, delay, jitter and service defines which type of service user request for such as video, audio, e-mail. QoS defines the full utilization of bandwidth and how to manage network resources.

The performance of various routing protocols is evaluated on IPv4 & IPv6 network. Four parameters are selected in order to study the performance of RIP, RIPng, OSPF-v2, OSPV-v3 and AODV [14] [15] [16] [17] [18].

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3.2. Discussion of parameters

3.2.1. Throughput

The throughput can be defined as how many bits transferred from one location to another in the given amount of time. Increases in the value of throughput show the performance of a network is good. It is measured in bits per second.

$$\mathrm{Th} = \frac{\mathrm{TBR}}{t_l - t_f} \qquad (1)$$

Where Th= Throughput in bits per second, TBR=Total Bytes received, t_l=last packet received time in sec, t_f= first packet received time in sec

3.2.2. Jitter

It is the variation in delay of received packets. It shows the difference between the delay of (i+1)thpacket and ithpacket.

$$J = \frac{\sum_{i=1}^{n}(D_{i+1} - D_i)}{n-1} \qquad (2)$$

If the value of jitter is low, then there is minimum delay between the received packets which shows good performance of the network.

3.2.3. End-to-End Delay

It is the time taken by the data packet to travel from source to destination. It is the difference between the time of the packet sent by the source and the time it successfully received by the destination. The lower the value of the end to end delay means better performance of the network.

$$D_{end} = T_d + P_d + Q_d + PR_d \qquad (3)$$

Where, D_{end} = End-to-end delay in sec, T_d = Transmission delay, P_d = Propagation delay, Q_d = queuing delay and PR_d = Processing delay.

$$\boldsymbol{T_d} = \frac{\boldsymbol{N}}{\boldsymbol{R_t}} \qquad (4)$$

N= number of bits , R_t= rate of transmission in bits per sec

$$P_d = \frac{D}{s} \qquad (5)$$

Where D= distance from the node to the next node and so is the propagation speed of the media

$$Q_d = T_d * Q_l \qquad (6)$$

Where, Q_l= length of queue, T_d = transmission delay

3.2.4. Packet Delivery Ratio

It is the ratio of the number of data packets successfully received by data packets sent. It also gives how many data packets are lost in the network. The higher value of PDR shows the best performance of the protocol. PDR is related to throughput. The high value of PDR gives high throughput.

$$PDR = \left(\frac{TPR}{TPS}\right) * 100 \qquad (7)$$

Where, TPR= total packets received, TPS= total packets sent

4. RESULTS AND DISCUSSIONS

4.1. Throughput

It has been observed from table 2 that the performance of AODV (IPv4) in all the three (wired, wireless and hybrid) networks is good due to the fact that AODV is an on-demand routing protocol. It creates a routing path when needed. AODV in IPv4 perform better due to the reason that header size (without padding) of IPv4 is smaller than IPv6. OSPFv3 gives low throughput value. All the protocols in wired network perform better as shown in figure1.The higher value of throughput shows good performance of the protocol.

Table 2: Throughput in Kilobits/s

		Wired	Wireless	Hybrid
IPv4	RIPv2	409.684	142.195	196.132
	OSPFv2	409.660	119.753	163.426
	AODVv4	415.674	160.238	193.900
IPv6	RIPng	409.691	122.158	184.157
	OSPFv3	409.666	109.104	117.510
	AODVv6	415.621	138.498	179.774

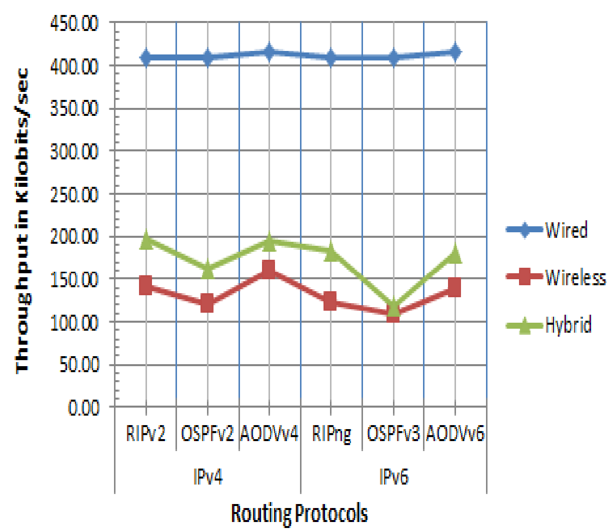

Figure 1: Statistics show Routing Protocols vs Throughput

4.2. Jitter

As shown in table 3 in the case of wired network, the jitter of RIPng is too less and OSPFv2 is high. In a wireless and hybrid network, AODV (IPv4) and AODV (IPv6) is low and OSPF-v3 is very high. The overall performance of AODV (IPv4) is

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good and OSPFv3 is high as compared to all three (wired, wireless and hybrid network). In figure 2, jitter of all the routing protocols in wired network is very less. The lower value of jitter shows the best performance of routing protocol.

Table3: Jitter in sec

Protocols		Wired	Wireless	Hybrid
IPv4	RIPv2	4.73E-08	7.19E-02	3.17E-02
	OSPFv2	1.02E-03	1.68E-01	5.29E-02
	AODVv4	4.30E-06	4.06E-02	3.04E-02
IPv6	RIPng	0.00E+00	1.14E-01	2.82E-02
	OSPFv3	1.02E-03	2.69E-01	5.75E-02
	AODVv6	1.92E-06	5.26E-02	2.25E-02

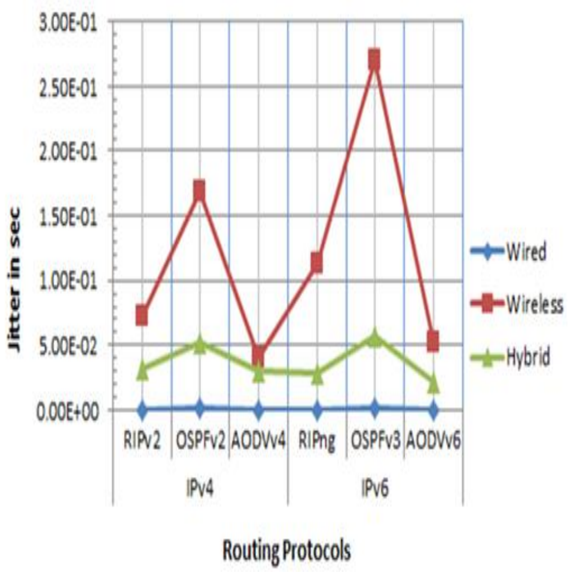

Figure 2: Statistics show Routing Protocols vs Jitter

4.3. End-to-End Delay

Table4: End to End Delay in sec

Protocols		Wired	Wireless	Hybrid
IPv4	RIPv2	9.05E-03	1.06E+01	7.37E+00
	OSPFv2	1.04E-01	1.42E+01	9.74E+00
	AODVv4	8.99E-03	3.57E+00	3.72E+00
IPv6	RIPng	9.16E-03	1.36E+01	5.43E+00
	OSPFv3	1.04E-01	1.44E+01	9.31E+00
	AODVv6	9.16E-03	7.06E+00	5.22E+00

From the results of an end -to- end delay, AODV (IPv4) in case of all the three (wired, wireless and hybrid) is very less and OSPF-v2 in wired and hybrid network and OSPF-v3 in a wireless network is very high shown in table 4. Figure 3 shows that there is a high delay in a wireless network due to less bandwidth. A number of packets are more than the number of packets that the network can handle.

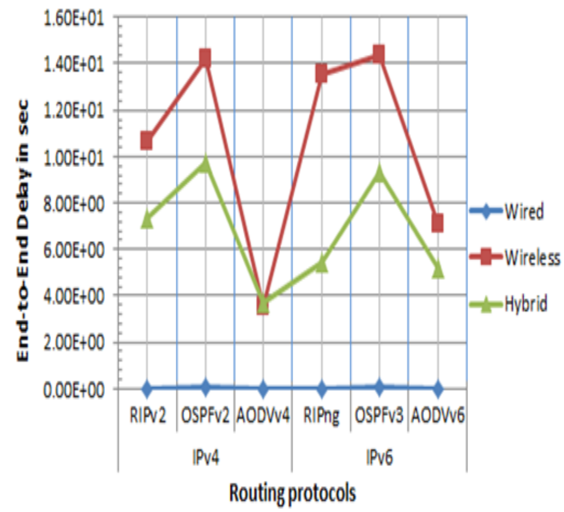

Figure 3: Statistics show Routing Protocols vs Delay

4.4. Packet Delivery Ratio (PDR)

Figure 4 shows the efficiency of the protocols in terms of successful delivery of data packets. Table 5 shows the performance of AODV (IPv4) in all three networks is very high due to the fact that AODV is on demand routing protocol, whereas the performance of RIPng in wired and OSPF-v3 in wireless and hybrid is low.

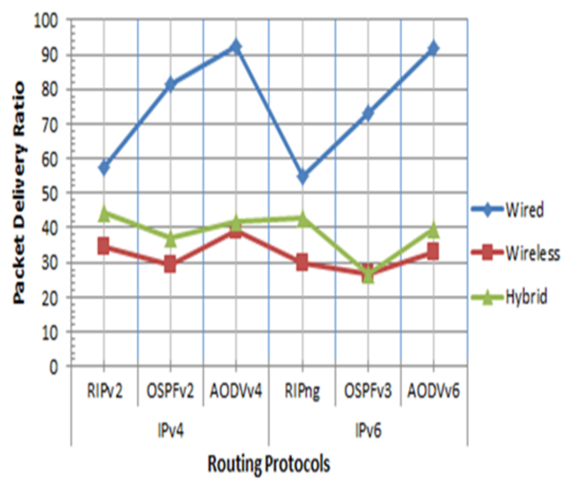

Figure 4: Statistics show Routing Protocols vs PDR

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Table 5: Packet Delivery Ratio

Protocols		Wired	Wireless	Hybrid
IPv4	RIPv2	57.7	34.7	44.6
	OSPFv2	81.3	29.1	37.2
	AODVv4	92.2	39	42
IPv6	RIPng	54.6	29.8	43.1
	OSPFv3	73.1	26.6	26.9
	AODVv6	92	32.9	39.8

The performance of various routing protocols is evaluated. Comparing with the wired and hybrid network, packet loss in the wireless network is high. The reason for packet loss in the wireless network is radio range. When the radio range increases the signal becomes weak, so result in packet loss. Another reason for packet loss that we observe is the size of the buffer. If the size of the buffer is full, packets are discarded by the router. We take note that packet loss occurs due to the size of the header. Theoretically, the header size of the IPv6 packet (40 bytes) is bigger than the IPv4 header (20-60 bytes), then the performance of routing protocols for an IPv6 network is down. Routing protocol AODV (IPv4) in the wired network perform better than all other protocols. The reason behind this is that AODV is on- demand distance vector routing protocol. Routes are established only when needed. On the other hand, the performance of OSPF-v3 is low.

5. CONCLUSION AND FUTURE WORK

In this paper, we have evaluated the performance of different routing protocols for IPv4 and IPv6 over wired, wireless and the hybrid network. Some reasons for packet loss that we observed are the size of the buffer, radio range, router load. From the results it has been observed that out of all protocols the performance of AODV (IPv4) is best. It has the maximum throughput and packet delivery ratio with minimum delay and jitter. The paper compares different routing protocols in terms of throughput, jitter, end-to-end delay and PDR which helps in designing the new protocol that can perform better. In the future, we want to extend our work to test routing protocols with different packet sizes and used the header compression technique to reduce the size of IPv6 header for better performance.

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