A Survey of Routing Protocols for Ad Hoc Networks Based on Update Mechanism

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***Abstract*—An essential matter for ad hoc networks is routing protocol design which is a major technical challenge due to the mobility of the nodes. Routing problem becomes more complex and challengeable, and it probably is the most addressed and studied problem in ad hoc networks. There are several classifications of Routing protocols are used to perform routing the information from source to destination. Classification methods help researchers and designers to understand distinct characteristics of a routing protocol and find its relationship with others. The main aim of this paper is to explore and to compare the concept of all routing protocol based on update mechanism. This classification divided into Table-Driven (Proactive), On-demand (Reactive), Hybrid routing protocols. Also, the comparison is provided based on the routing mechanism and information used to make routing decisions. Also this paper presents an overview of routing issues in different cases as well as a detailed discussion of and their relative performance. To compare and analyze an ad hoc network routing protocols, appropriate classification methods are important.**

***Index Terms*—Ad hoc networks, routing protocols, performance analysis, update mechanism.**

I. Introduction

Wireless ad hoc networks are currently deployed in many areas of interest from homes, markets, schools and universities to inaccessible terrains, disaster places, etc. Mobile networks can be classified into infrastructure networks and mobile ad hoc networks which called MANET according to their dependence on fixed infrastructures [1]. An ad-hoc network require no centralized administration or fixed network infrastructure such as base stations or access points and temporarily formed nodes, each node presents both as a router and as a host and even the topology of network may also change rapidly according to the application or environment. This happen over wireless channels without any fixed network interaction and centralized administration. There are several characteristics of Ad Hoc networks that make their operations more complicated than ordinary infrastructure networks, these include: mobility, limited resources, high error rates due to broadcast nature of radio channel, limited bandwidth, hidden and exposed terminal problem and of particular interest routing Protocols. Ad Hoc network has wide application in industrial and commercial field involving cooperative mobile data exchange, inexpensive alternatives or enhancement to cellular-based mobile network infrastructures. Ad Hoc network has potential applications in the locations where setting of infrastructure networks is not possible. The necessity that the Routing Protocol must be able to respond rapidly to the topological changes in the network, this will help to get a wide understanding of the problem and can also be used to develop or to extend proposed schemes [1]-[3].

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II. Prorouting Protocols

Routing in Ad Hoc networks been an active area of research and in recent years a lot of protocols have been introduced for addressing the problems of routing, reviewed in next sections. A routing protocol is needed whenever a packet needs to be transmitted to a destination via number of nodes from specific source and there are a lot of routing protocols have been proposed for such kind of ad hoc networks in both mobile and wireless. These protocols have to find a route for packet delivery and deliver the packet to the correct destination. The studies on various aspects of routing protocols have been an active area of research for many years. Classification methods help researchers and designers to understand distinct characteristics of a routing protocol and find its relationship with others according to the applications. Based on the routing information update mechanism, routing protocols can be broadly classified into three types as a) Table Driven Protocols or Proactive Protocols and b) On-Demand Protocols or Reactive Protocols. c) Hybrid Routing protocols integrated of a and b. Proactive protocols rely upon maintaining routing tables of known destinations, this reduces the amount of control traffic overhead that proactive routing forwarded directly by using known routes. Reactive Protocols use a route discovery process to flood the network with route query requests when a packet needs to be routed using source routing or distance vector routing [2]-[4]. This paper gives a good view about several type of routing protocols discussed in this paper as shown in Fig. 1.

III. Table-Driven (Proactive)

A proactive routing protocol is called "table driven" routing protocol according to their mechanism. Using a proactive routing protocol nodes in a mobile ad hoc network continuously evaluate routes to all reachable nodes (Neighbors) and attempt to maintain consistent, up-to-date routing information at any movement. Therefore, a source node can get a routing path immediately if it needs one. In proactive routing protocols, all nodes need to maintain a consistent view of the network topology. When a network topology change occurs. Examples of this type are: DSDV, WRP, CGSR, and STAR. False sequence has been

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established the attacker will continuously send out new packets to update the value to determine the new location. Therefore more hosts will be cheated as a single misbehaving node can pose a serious threat for the entire network. [2], [5], [6].

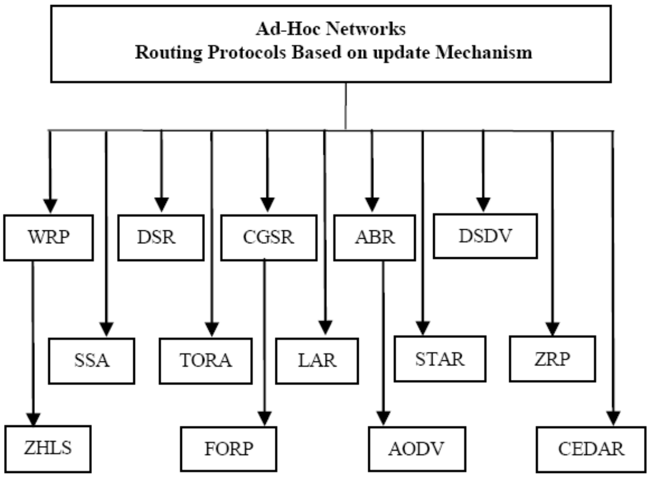

Fig. 1. Routing protocols.

A. Destination-Sequenced Distance-Vector Routing Protocol (DSDV)

The destination sequenced distance vector routing protocol (DSDV) is an extension of classical bellman ford routing mechanism. DSDV maintains consistent network view via periodic routing updates. Routing information is stored inside routing tables maintained by each node. New route broadcasts contain the address of the destination, the number of hops to reach destination, the sequence number of the destination and a new sequence number unique to broadcast. A route with a recent sequence number is considered as a fresh route. If sequence numbers are found to be the same than the route with better metric will be selected. The route updates of DSDV can be either time-driven or event-driven. When a neighbor device receives the broadcasted routing message and knows the current link cost to the device, it compares this value and the corresponding value stored in its routing table. If changes were found, it updates the value and re-computes the distance of the route which includes this link in the routing table. Every node periodically transmits updates including its routing information to its immediate neighbors. Less delay is involved in the route setup process because of the availability of routes to all destinations at all times. The existing wired network protocols are adaptable to ad hoc wireless networks because they can be made [1], [6], [7].

B. Wireless Routing Protocols (WRP)

The Wireless Routing Protocol, as proposed by Murthy and Garcia-Luna-Aceves is a table-based protocol similar to DSDV that inherits the properties of Bellman-Ford Algorithm. The main goal is maintaining routing information among all nodes in the network regarding the shortest distance to every destination. Wireless routing protocols (WRP) is a loop free routing protocol. A node sends update message when it detects a neighbor link state change or receives the update message from its neighbor. The recipient modifies its distance and seeks the best route at the time of message receiving. Distance table (DT), Routing table (RT), Link-cost table (LCT), Message retransmission list (MRL) table. In case of link failure between two nodes, the nodes send update messages to their neighbors. WRP belongs to the class of path-finding algorithms with an important exception. The MRL list is needed to be updated. It has faster convergence and involves fewer table updates. Then WRP sending hello message to disallow a node to enter sleep mode. It is not suitable for highly dynamic and also for very large ad hoc wireless networks. The hello packets consume bandwidth and do not allow a node to enter sleep mode [1], [4], [7].

C. Cluster Gateway Switch Protocols (CGSP)

The Cluster-head gateway switch routing protocol (CGSR) is a clustered multi-hop mobile wireless approach is different from traditional link state routing protocol such as DSDV which uses single table for same purpose. Keeping information inside three different tables limits node performance to certain extent. CGSR uses similar proactive routing mechanism as DSDV. Using CGSR, mobile nodes are aggregated into clusters and a cluster-head is elected for each cluster. Gateway nodes are responsible for communication between two or more cluster heads. Nodes maintain a cluster member table that maps each node to its respective cluster-head. A node broadcasts its cluster member table periodically. After receiving broadcasts from other nodes, a node uses the DSDV algorithm to update its cluster member table. In addition, each node maintains a routing table that determines the next hop to reach other clusters. Better bandwidth utilization is possible because CGSR uses a partial coordination between nodes by electing cluster heads. Increases in path length and instability in the system at high mobility when the rate of change of cluster –heads is high [1], [7].

D. Source Tree Adaptive Routing Protocols (STAR)

In STAR each node maintains a source tree which consists of its preferred links to each destination. The source tree is calculated on the information of its own links and the source trees reported by its neighbors. Any changes in a source tree are reported to the neighbors in an incremental manner. The source tree and neighbor information establish the partial topology information in each node. This information is used by a route selection algorithm to obtain the route table with destination and next hop. The STAR protocol is also based on the link state algorithm. Each router maintains asource tree, which is a set of links containing the preferred paths to destinations. This protocol has significantly reduced the amount of routing overhead disseminated into the network by using a least overhead routing approach (LORA), The link state update messages are used to update changes of the routes in the source trees. Since these packets do not time out, no periodic messages are required. STAR has very low communication overhead. It reduces the average control overhead by using the approach of LORA [5], [7], [8].

IV. On-Demand (Reactive)

Reactive Protocols use a route discovery process to flood the network with route query requests when a packet needs to be routed using source routing or distance vector routing Source routing uses data packet headers containing routing information meaning nodes don't need routing tables. But features very little control traffic overhead and has typically lower memory usage than proactive alternatives, this increases the scalability of the protocol [2].

A. Dynamic Source Routing (DSR)

Dynamic Source Routing (DSR) is an on-demand/reactive protocol. It doesn't use periodic updates. It computes the routes when necessary and then maintains them. Source routing is a routing technique in which the sender of a packet determines the complete sequence of nodes through which the packet has to pass. Dynamic Source Routing (DSR) is an Ad Hoc routing protocol which employs the theory of source-based routing rather than table-based. This protocol is source-initiated rather than hop-by-hop. This protocol requires each transmitted packet to carry the full address from the source to the destination. This mechanism in DSR makes it not scalable and not to perform well in large networks, since the amount of overhead carried in these packets is increased dramatically as the size of network grows. There are two basic functions of DSR protocol: Route discovery and Route maintenance. Every node maintains a cache to store recently discovered paths. When a node needs to transmit a packet, it first checks its cache whether it has an entry for the destination. If yes then it uses that route to transmit the packet. Also it appends its source address on the packet. In case there is no a valid entry in the cache or the entry is expired, the sender broadcasts a route request packet to all its neighbors asking for a path to the destination. The sender waits until the route is discovered. When the route request packet arrives to any intermediate nodes, they check whether they know the corresponding destination. If they have route information, they send back a route reply packet to the destination. Otherwise they broadcast the same route request packet. When the route is discovered, the sender will insert it in it routing table entries. For route maintenance whenever a link in a source route is broken the source node is notified using a route error packet [3], [5], [8], [9] clearly for this protocols one of the main benefit of DSR protocol is that there is no need to keep routing table so as to route a given data packet as the entire route is contained in the packet header. The limitations of DSR protocol is that it is not scalable to large networks and even requires significantly more processing resources than most other protocols. Basically, In order to obtain the routing information, each node must spend lot of time to process any control data it receives [10].

B. Ad Hoc on-Demand Distance Victor (AODV)

AODV is a derivative of Destination-Sequenced. Distance-Vector (DSDV) routing protocol which is collectively based on DSDV and DSR. The main goal is to minimize the requirement of broadcast transmissions. When a node needs to send a data packet to a destination node, the entries in route table are checked. If route is there, the data packet is forwarded to the next hop toward the destination. If it is not there, the route discovery process is initiated. The source node will create a route request packet containing its IP address, its current sequence number, the destination's IP address, the destination's last sequence number and broadcast ID. The broadcast ID is incremented each time the source node initiates route request packet. Basically, the sequence number used to determine the freshness of each data packet and the broadcast ID with the IP address together form a unique identifier for route request. The source node broadcasts the route request packet to its neighbors and then sets a timer to wait for a reply. To process the route request, the node sets up a reverse route entry for the source node in its route table. This helps to know how to forward a route reply to the source. The source node sets the Time to Live (TTL) value of the route request packet to an initial start value. If there is no route reply during the discovery period, the next route request packet is broadcasted with a TTL value increased by an increment value. This technique is used to increase the search area. [7] AODV uses the least congested route instead of the shortest route and it also supports both uni-cast and multicast. It also responds very quickly to the topological changes that affects the active routes. AODV does not put any additional overheads on data. The disadvantages of AODV protocol are that it is possible that a valid route is expired and the determination of a reasonable expiry time is difficult. In addition, it is performance decrease rapidly in a highly dynamic environment. The security of AODV is weak as it is based on the assumption that all nodes must cooperate to find the route. [10]

C. Temporally Ordered Routing Algorithm (TORA)

TORA is a non-demand routing protocol. It provides multiple routes to a destination. It establishes routes quickly and minimizes control overhead. The idea of shortest-path routing is considered of secondary importance and longer routes are often used to avoid the overhead of discovering newer routes. TORA uses Directed Acyclic Graph (DAG) rooted at a destination to build and maintain routes. Information may flow from nodes with higher heights to nodes with lower heights. Information can therefore be thought of as a fluid that may only flow downhill and cannot flow uphill. The key design concept of TORA is localization of control packets to a very small number of nodes that are close to the broken link. To accomplish this, nodes need to maintain the routing information about adjacent nodes. Links are assigned based on the relative height metric of neighboring nodes. During of mobility the DAG is broken and the route maintenance process initiated to reestablish a DAG rooted at the destination. Timing is an important factor for TORA because the height metric depends on the logical time of the link failure. TORA's route erase function is essentially involving flooding a broadcast of clear packet (CLR) throughout the network to erase invalid routes. [10], [11].

D. Location-Aided Routing (LAR)

This routing protocol reduces the control overhead by using the location information provided by GPS system. LAR defines two geographical areas: Expected Zone and Request Zone. Expected Zone is the area where the destination node is estimated to be present, giving its past location and mobility information. Request Zone is the area within which RREQ packet are allowed to be processed and forwarded by intermediate nodes. Request Zone is the smallest rectangle that includes the source node and the Expected Zone. If the sender node is in the Expected Zone, then the Request Zone is reduced to the Expected Zone. The more accurate location information available the less error in determining the Expected Zone, and therefore more routing efficiency. If the route discovery process fails the first time, then the Request Zone will be extended and additional area will be considered to compensate the inaccuracy of location and mobility information. Two algorithms LAR1 and LAR2 are used by intermediate nodes to decide whether to forward or drop the RREQ packet. With LAR1, the source node specifies the Request Zone in the RREQ packet and broadcast it to its neighbors. Intermediate nodes check its location information to determine whether it is inside the Request Zone or not. Destination node, upon receiving the RREQ packet it responds by sending a RREP packet back to the source node. This RREP packet contains the destination node current location and mobility information. Such information can be used by the source node for future route discovery process. With LAR2, the source node includes the distance between itself and the destination node in the RREQ packet. When an intermediate node receives a RREQ packet, it compares the distance between itself and the destination node with the one in the RREQ packet it has received. If the node is closer to the destination than the node sent the RREQ packet, this node is allowed to process it and update it with its distance to the destination node and then forwards it to its neighbor, otherwise it is dropped. The major advantage of LAR is that it reduces the control overhead by limiting the search area to the Request Zone and therefore increases the bandwidth utilization. LAR relies on location information provided by GPS system, hence it can't be used where this service is not available. [11]

E. Associativity-Based Routing (ABR)

It is a beacon-based on-demand routing protocol. ABR selects routes based on link stability. Each node in the network counts the beacon messages from its neighbors and marks those links as stable or unstable links. When a source node wishes to send a packet to a destination node, it originates a RREQ packet and broadcasts it throughout the network. The destination node receives this RREQ packet from different paths. Each RREQ packet received by the destination node has the path that it has traversed and the stability status of each hop in the path. The destination node waits for a period of time called route select time to receive all the RREQ packets corresponding to the same route request process. The destination node then selects the most stable path even if it is not the shortest. In ABR, all intermediate nodes are allowed to rebroadcast the RREQ packet even if it is received through an unstable links. The stability information are used only during the route selection process at the destination node. Route maintenance process repairs a broken links locally by sending a packet called a local query packet LQ by the intermediate node that detects the link failure with a limited TTL equal to the remaining hops towards the destination. If the first attempt fails the process will be repeated by the previous node in the path and so on until the half way between the source and the destination. In ABR, using the most stable links results in fewer path breaks, in turn, reduces the frequent flooding due to route maintenance process. Repetitive LQ broadcasts may result in high delays during route repair process. [12]

F. Signal Stability-Based Adaptive Routing Protocol (SSA)

Signal stability-based adaptive routing protocol is an on-demand routing protocol that selects routes based on signal strength. SSA is a beacon-based, in which each node in the network sends beacon messages periodically to its neighbors. This protocol uses the strength of the beacon signal to classify links as stable or unstable and stores these information in a table called signal stability table SST. SSA consists of two parts: Forwarding Protocol FP and Dynamic Routing Protocol. DRP maintains the routing tables and FP is performing the packet forwarding. In SSA, nodes that receive RREQ packet through an unstable link are not allowed to process and forward it. The first RREQ packet that reaches to the destination through a stable path is used to initiate a RREP packet back to the source node. If the attempt to find a stable path to the destination through stable links fails, SSA floods the RREQ packet throughout the network without considering the stability condition of the links. When a link breaks, the end nodes of the broken link send a notification packet to the source and the destination nodes. The source node reinitiates the process over again. The main advantage of the SSA is sets up a stable route to avoid frequent link breaks and therefore increase the bandwidth utilization. The disadvantage of the protocol is that the selected route may be not the shortest path to the destination as it applies the condition of the link stability during the path finding process. Also, the route set up time may increase if the stable path to the destination is not exist and the protocol adapt to this by repeating the process and consider the weak links. [13]

G. Flow-Oriented Routing Protocol (FORP)

Flow-Oriented Routing Protocol (FORP) is an on-demand routing protocol that utilizes a prediction-based multi-hop-handoff mechanism. FORP is designed to support real-time and time sensitive applications in ad hoc wireless networks. The multi-hop-handoff mechanism is about how to avoid link breaks that affect the quality of services for real-time applications proactively. The main idea of this prediction mechanism is to use the location and mobility information to estimate the link expiration time LET. Also, the route expiration time RET which is the minimum LET value of the entire wireless path from the source to the destination. Each node in the network should be able to estimate LETs to its neighbors by using the location and mobility information provided by the GPS system. If a sender node has a packet to be send to a destination node, it originates a Flow-REQ packet and broadcasts it to its neighbors. This Flow-REQ packet carries a sequence number, identification number and the source and destination information. Intermediate nodes, upon receiving the Flow-REQ packet, appends its address and LET of the path it has arrived through and then rebroadcasts it to its neighbors. The destination node will receive this Flow-REQ from different paths. The path with higher RET will be selected and a Flow-Set up packet will be sent back to the source node through that wireless path. FORP proactively executes the route maintenance by finding an alternative path before the

RET of the current path expires and before the path breaks. The destination node originates a Flow-Handoff packet before the RET expires, and broadcasts it through the network to find an alternative path with better RET and switches to the new path to avoid link breaks and data loss. In this case the source node upon receiving the Flow-Handoff packet, will chose the route with better RET to be used next. The major advantage of FORP is that it uses the LET and RET to avoid link breaks and therefore reduces packet loss and enhance the quality of services. Also, the proactive route maintenance mechanism works well when the topology is highly dynamic. The disadvantage of this protocol is that it requires time synchronization which results in more control overhead. Also, its dependency on GPS system makes it unusable when such service is not available [14], [15].

V. Hybrid Routing Protocols

These protocols combine effectively both the proactive and reactive routing protocols, this mixture can provide better result by take the advantage of reducing the traffic overhead from proactive, in the same time exploit the reduction of rout discovery delays in the reactive. The following are some of the most important protocols like CEDAR, ZRP, and ZHLS. [14], [15]

A. Core Extraction Distributed Ad Hoc Routing Protocols (CEDAR)

Core Extraction Distributed Ad Hoc Routing (CEDAR) protocol [1], [6] establishes a core nodes in the network which is used to transmit packets. The routing establishment uses reactive routing scheme and which performed by core nodes. There must be one core node among every three hops. The core nodes are dynamically elected by distributed algorithm to form the core of the network. The path between two core nodes is called virtual path. Core nodes are used to perform the packet transmission over the network in unicast mode. In order to achieve this transmissions efficiently, each core node know its neighboring core nodes. If the core node moves away, all the nodes that were related to it will find a new core. CEDAR consists of two phases: first find a core path from source node to destination. Second: finding Quality of Serves (QoS) feasible path with highest bandwidth. The source core send a route request to the neighbored core node by using the core broadcast, then the core node that have a destination as a member replies to the source core, then the core path established. In the second phase, the QoS path which is the widest shortest path is used to establish a route from the source to the destination with the required band width. If a path is broken between two nodes node n and node u, node n send a notification to the source node, starts re-computation of a route from itself to destination, and drops every subsequent packet that it receives until the re-computation gets completed. Once source node receive the notification, it stops transmitting immediately and starts reinitiating the route establishing from itself to the destination [14], [15] .

B. Zone Routing Protocol (ZRP)

Zone Routing Protocol is a hybrid routing protocol. It effectively combines the advantages from proactive and reactive routing. ZRP divides its network in different zones. That's the nodes local neighborhood. Each node may exist in multiple overlapping zones, and each zone may be of a different size. The size of a zone is given by a radius of length, where the number of hops is the perimeter of the zone. Each node has its own zone. When a node send packet, the Intra Zone Routing Protocol (IARP) is used in order to transmit to the interior nodes of its zone. There are routes inside the zone, and each node must update the routing information in order to determine interior and the peripheral nodes as well as maintain a map of which nodes can be reached locally. Inter Zone Routing Protocol (IERP): the reactive routing is used to communicate between nodes of different zones. It provide better route discovery. The route discovery is done by using process called Broadcasting that uses a Broadcast Routing Protocol (BRP) to only transmit route requests to peripheral nodes. If the destination is not in the interior zone a broadcast will send to the peripheral node, and if any peripheral node find the destination, it send a rout reply to establish the path. Otherwise the peripheral node will rebroadcast the Rout Request again until the destination founded [5], [10].

TABLE I: Comparison of Routing Protocols

Protocols	Structure	Route	Update	Base
DSDV	Flat/ Uniform	Source	Neighbor	Proactive
WRP	Flat/ Uniform	---	Neighbor	Proactive
CGSR	Hierarchical	---	Cluster	Zone
STAR	Flat / Uniform	---	Neighbor	Proactive
DSR	Flat/ Uniform	Multiple	Source	Reactive
AODV	Flat/ Uniform	Distance	Source	Reactive
TORA	Flat /Uniform	Complex	Neighbor	Reactive
CEDAR	Flat/ Non	---	---	Core Node
ZRP	Flat/ Non	No	Neighbor	Zone
ZHLS	Hierarchical	---	Neighbor	Zone

C. Zone-Base Hierarchical Link State Routing Protocol (ZHLS)

The Zone-based Hierarchical Link State routing (ZHLS) is a hybrid routing protocol. In ZHLS, the mobile nodes are required to know their physical locations by using GPS. The network is divided into non-overlapping zones based on geographical information. [4], [5] ZHLS uses a hierarchical addressing scheme that contains zone ID and node ID. Each node knows its zone ID according to its location and the pre-defined zone map is known by all nodes in the network. A virtual link connects two zones if there exists at least one physical link between the zones. A two-level network topology structure is defined in ZHLS, the node level topology and the zone level topology. Respectively, there are two kinds of link state updates, the node level LSP (Link State Packet) and the zone level LSP. A node level LSP contains the node IDs of its neighbors in the same zone and the zone IDs of all other zones. A node periodically broadcast its node level LSP to all other nodes in the same zone. Therefore, through periodic node level LSP exchanges, all nodes in a zone keep identical node level link state information. In ZHLS, gateway nodes broadcast the zone LSP throughout the network whenever a virtual link is broken or created. Consequently, every node knows the current zone level topology of the network. The source firstly checks its intra-zone routing table before send packet to determine whether the destination is in the same zone in order to send it. Otherwise, the source sends a location request to all other zones through gateway zone. After a node of the gateway zone, in which the destination node resides, receives the location request, it replies with a location response containing the zone ID of the destination. The zone ID and the node ID of the destination node will be specified in the header of the data packets originated from the source. During the packet forwarding procedure, intermediate nodes except nodes in the destination zone will use inter-zone routing table, and when the packet arrives the destination zone, an intra-zone routing table will be used. [10], [14], [15].

VI. Conclusions

In this paper, a survey of Ad Hoc routing protocols is provided based on update mechanism because of there are several classifications, and collecting a data from latest of international journals. highlighting their characteristics and an effort has been made to concentrate on the comparative study and performance analysis of various on demand/reactive/Hybrid routing protocols to give general comparison for all discussed protocols as shown in Table I to know all details about each protocols with compare to others like structure routing, update mechanism, and base on type uniform or non uniform. Off course no single protocol is the best for all circumstances; each protocol has definite benefits and limitations and is well suited for certain situation. Some of the most prominent issues are bandwidth constraints and limited power of mobile devices. An ad hoc network is a collection of wireless mobile nodes dynamically forming a temporary network without the use of any network infrastructure or centralized administration. Much of the routing mechanisms are different. In particular mechanism uses to determine the most updated path. Finally Ad-hoc wireless and mobile networks technology is rapidly growing. It has been further concluded that due to the dynamically changing topology and infrastructure less, decentralized characteristics, security and power awareness. There are many challenges that need more attention of researchers.

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