International Journal of Enhanced Research in Management and Computer Applications
ISSN: 2319-7471, Vol. 4 Issue 8, August-2015

A Comprehensive Review of Routing Protocols in Heterogeneous Wireless Networks

Deepak Sharma[1], Col. (Dr.) Suresh Kumar[2]

[1]Research Scholar, U.I.E.T., MDU, Rohtak
[2]Assistant Professor, ECE, U.I.E.T., MDU, Rohtak

ABSTRACT

In recent years, with the evolution of mobile ad hoc networks the popularity of wireless communications systems can be seen almost everywhere in the form of cellular networks, WLANs and WPANS. Furthermore, even small portable devices are fully equipped with various communication interfaces for building a heterogeneous environment in terms of access technologies. The future heterogeneous environments integrate various wireless access technologies such as WLANs, WMANs and WWANs, with in an individual network architectures. It is envisioned that the next generation wireless systems would provide convergence of various wireless network technologies so as to have global connectivity .In this paper we present a review of the various routing protocols present in the Mobile Adhoc Networks (MANETs) and the review of different wireless access integration technologies and their comparisons.

Keywords: Mobile Ad hoc Networks, Heterogeneous Networks, AODV, DSR, DSDV, iCAR, MCN.

1. INTRODUCTION

The rapid growth in both wired and wireless technologies has made communication more secure, reliable and faster. The fact that anyone can be called or texted from any place around the globe at any time has become extremely convenient. The advent of the internet has made most of information easily accessible and now we expect the same on the go. Wireless communications have been in constant evolution and development for the past few years. The best example cited is the cellular networks which provide people with communication services along with the freedom of movement. Unfortunately physical constraints that arise when working with wireless technology make it difficult to provide such services especially indoors. Thus we have to work within the current environment and find solutions everywhere to extend coverage. [3]

Wireless networks provide connection flexibility between users in different places. Moreover, the network can be extended to any place or building without the need for a wired connection. Wireless networks are classified into two categories; Infrastructure networks and Ad Hoc networks

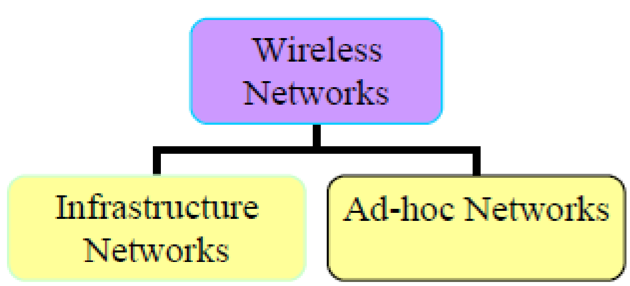

Figure 1: Wireless Networks Classification

Infrastructure networks An Access Point (AP) represents a central coordinator for all nodes. Any node can join the network through AP. In addition, AP organizes the connection between the Basic Set Services (BSSs) so that the route is ready when it is needed. However, one drawback of using an infrastructure network is the large overhead of maintaining the routing tables. Infrastructure network as shown in Figure 2

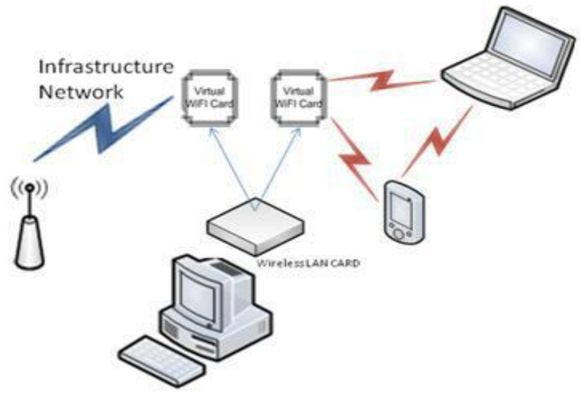

Figure 2: Infrastructure network

AD HOC NETWORKS

A wireless ad hoc network is a decentralized wireless network. The network is ad hoc because it does not rely on a preexisting infrastructure, such as routers in wired networks or access points in managed (infrastructure) wireless networks [1]. Ad Hoc networks do not have a certain topology or a central coordination point. Therefore, sending and receiving packets are more complicated than infrastructure networks.

.

Figure 3: Ad Hoc network

Nowadays, with the immense growth in wireless network applications like handheld computers, PDAs and cell phones, researchers are encouraged to improve the network services and performance. One of the challenging design issues in wireless Ad Hoc networks is supporting mobility in Mobile Ad Hoc Networks (MANETs). The mobility of nodes in MANETs increases the complexity of the routing protocols and the degree of connection's flexibility. However, the flexibility of allowing nodes to join, leave, and transfer data to the network pose security challenges [4]. A MANET is a collection of mobile nodes sharing a wireless channel without any centralized control or established communication backbone.

MANET has dynamic topology and each mobile node has limited resources such as battery, processing power and on-board memory[4] This kind of infrastructure-less network is very useful in situation in which ordinary wired networks is not feasible like battlefields, natural disasters etc. The nodes which are in the transmission range of each other communicate directly otherwise communication is done through intermediate nodes which are willing to forward packet hence these networks are also called as multi-hop networks. MANET [2] as shown in Figure 4

Mobile Ad Hoc Networks are networks where nodes function both as a host and routers. These nodes are able to move around freely easily inside the network but are also capable to enter and exit the network at any time they desire. The drawback of this mobility is that the routing algorithms become impossible to follow as all nodes are constantly moving. An important factor in the MANET's is the Transmission Power (Tx) thus if a mobile node is using its resources in forwarding data packets for other nodes its own battery life will suffer.

Figure 4: MANET

This feature also makes the MANET very much reliable and trustworthy but at the same time also being more attacked upon also. For mobile communications one main aspect of the communication shift paradigm is the successful development is traditional single hop cellular systems where a mobile station (MS) communicates directly with a base station (BS). The success of the second generation (2G) cellular networks and the clouds of 3G over our heads the need for higher data rates and bandwidth is an important concern for the industry. Another paradigm of the mobile communications is the multihop ad hoc networks which are infrastructureless, self organizing, rapidly deployable without any site planning unlike traditional cellular networks. Nodes can join and leave without any restriction placed on them. Thus it works on the concept of peer to peer networks. Thus every node can act as the intermediary station that relays packets of other nodes towards their destinations that otherwise cannot be reached using a single hop transmission. MANETs are easy to deploy because of their use of unlicensed spectrum of IEEE 802.11.

However this architecture has its own set of drawbacks which include less reliable performance as the channel connection and interference between nodes are more difficult to predict or control. Another failure reason is the multihop paths between source destinations are more vulnerable to the node mobility and node failure. Consider a scenario, in a university campus where a large number of mobile users that can act as relay MSs, are spread over the campus. At noon, the users may flock towards the cafeteria and the users in close proximity could form a multihop network. At around 2 PM, the users would leave the cafeteria and move to their offices and other locations of the university thus resulting for those people who were using their bandwidth to be completely cut off. Such a situation could be avoided if we could form a network which is a combination of both cellular and MANETs. [5]Thus the limitations of both the cellular networks and also the MANETs led the researchers to search for a architecture that combines both the advantages of each and present a protocol which enhances communication and reliability for the end user. Thus the traffic can be shared among the several BSs and MSs and thus all users will be able to take advantage of the bandwidth

2. HETEROGENEOUS WIRELESS NETWORK

The future of wireless communication lies in the ubiquitous networks that will be able to provide availability anywhere. These networks will be a combination of both the wired and a wireless network that is a Cellular network combined with IEEE802.XX networks where you can access both the network through access points and also through direct connection with the base station. Thus a Heterogeneous communication network provides transparent and self configuring able WLAN. The basic components are mobile stations (MS's), BS's/ APs. And a core (IP) network serving as the communication bridges for MS's. WLAN's can operate in infrastructure e.g. single hop mode where connectivity is provided by the AP or in MANET mode where devices can communicate with each other through multihop routing. A connection from a MS to a BS/AP can be established by a single hop or using multihop when the MS is out of the coverage of the corresponding BS/AP as shown in Figure.5. [6]. Although there is still a far of time to when the heterogeneous networks will be implemented there are three unique features significantly affecting the design of integrated solutions, namely , the availability of multiple interfaces for a MS, the integration of cellular networks and WLAN's and multihop communication.

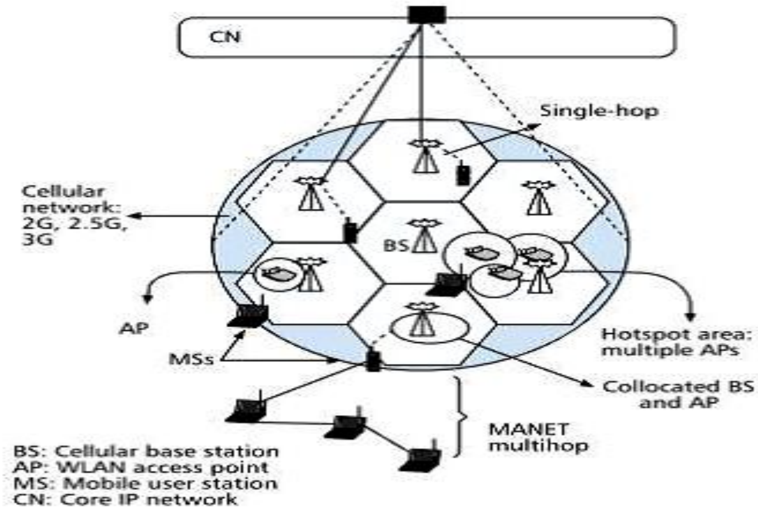

Figure 5 . Heterogeneous Network Architecture

These issues need to be addressed to provide an integrated transparent and self configurable service.[7] Heterogeneous networks will require the maintenance and configuration of multi-hop paths and available network interfaces due to the transient nature of the networks (relay MSs). The real challenge is to devise algorithms to discover and cope up with changing topology of the network. Consider a scenario, in a university campus where a large number of mobile users that can act as relay MSs, are spread over the campus. At noon, the users may flock towards the cafeteria and users in close proximity could form a multi-hop network. At around 2 pm, the users would leave the cafeteria and move to other parts of the campus. In such a scenario, the network topology changes with the time of the day. The issue is how to recreate and reconfigure the topology of such a dynamic network. The variety of wireless access networks in a heterogeneous environment introduces a number of challenges for connection management such as maintaining valid multi-hop paths and available network interfaces.

3. CLASSIFICATION OF ROUTING PROTOCOLS

Routing protocols define a set of rules which governs the journey of message packets from source to destination in a network. In MANET, there are different types of routing protocols each of them is applied according to the network circumstances. Figure 1 shows the basic classification of the routing protocols in MANETs [1]

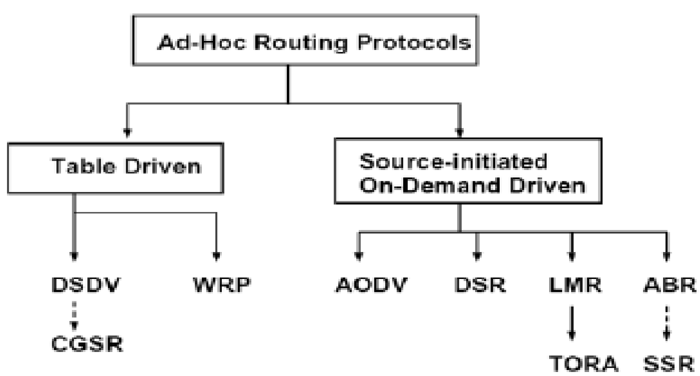

Figure 6: Classification of Routing protocols

3.1 PROACTIVE ROUTING PROTOCOLS

Proactive routing protocols are also called as table driven routing protocols. In this every node maintain routing table which contains information about the network topology even without requiring it[2]. This feature although useful for datagram traffic, incurs substantial signaling traffic and power consumption [8]. The routing tables are updated periodically whenever the network topology changes. Proactive protocols are not suitable for large networks as they need to maintain node entries for each and every node in the routing table of every node [9]. These protocols maintain different number of routing tables varying from protocol to protocol. There are various well known proactive routing protocols. Example: DSDV, OLSR, WRP etc.

3.1.1 DYNAMIC DESTINATION-SEQUENCED DISTANCE-VECTOR ROUTING PROTOCOL (DSDV)

DSDV [10] is developed on the basis of Bellman–Ford routing [11] algorithm with some modifications. In this routing protocol, each mobile node in the network keeps a routing table. Each of the routing table contains the list of all available destinations and the number of hops to each. Each table entry is tagged with a sequence number, which is originated by the destination node. Periodic transmissions of updates of the routing tables help maintaining the topology information of the network. If there is any new significant change for the routing information, the updates are transmitted immediately. So, the routing information updates might either be periodic or be an event driven. DSDV protocol requires each mobile node in the network to advertise its own routing table to its current neighbors. The advertisement is done either by broadcasting or by multicasting. By the advertisements, the neighboring nodes can know about any change that has occurred in the network due to the movements of nodes. The routing updates could be sent in two ways: one is called a “full dump” and another is “incremental”. In case of full dump, the entire routing table is sent to the neighbors, where as in case of incremental update, only the entries that require changes are sent [12].

3.1.2 WIRELESS ROUTING PROTOCOL (WRP)

WRP [13] belongs to the general class of path-finding algorithms [14,15,16], defined as the set of distributed shortest path algorithms that calculate the paths using information regarding the length and second-to-last hop of the shortest path to each destination. WRP reduces the number of cases in which a temporary routing loop can occur. For the purpose of routing, each node maintains four things:

1. A distance table
2. A routing table
3. A link-cost table
4. A message retransmission list (MRL).

WRP uses periodic update message transmissions to the neighbors of a node. The nodes in the response list of update message (which is formed using MRL) should send acknowledgments. If there is no change from the last update, the nodes in the response list should send an idle Hello message to ensure connectivity. A node can decide whether to update its routing table after receiving an update message from a neighbor and always it looks for a better path using the new information. If a node gets a better path, it relays back that information to the original nodes so that they can update their tables. After receiving the acknowledgment, the original node updates its MRL. Thus, each time the consistency of the routing information is checked by each node in this protocol, which helps to eliminate routing loops and always tries to find out the best solution for routing in the network [12]

3.1.2 CLUSTER GATEWAY SWITCH ROUTING PROTOCOL (CGSR)

CGSR [17] considers a clustered mobile wireless network instead of a flat network. For structuring the network into separate but interrelated groups, cluster heads are elected using a cluster head selection algorithm. By forming several clusters, this protocol achieves a distributed processing mechanism in the network. However, one drawback of this protocol is that, frequent change or selection of cluster heads might be resource hungry and it might affect the routing performance. CGSR uses DSDV protocol as the underlying routing scheme and, hence, it has the same overhead as DSDV. However, it modifies DSDV by using a hierarchical cluster-head-to-gateway routing approach to route traffic from source to destination.

International Journal of Enhanced Research in Management and Computer Applications
ISSN: 2319-7471, Vol. 4 Issue 8, August-2015

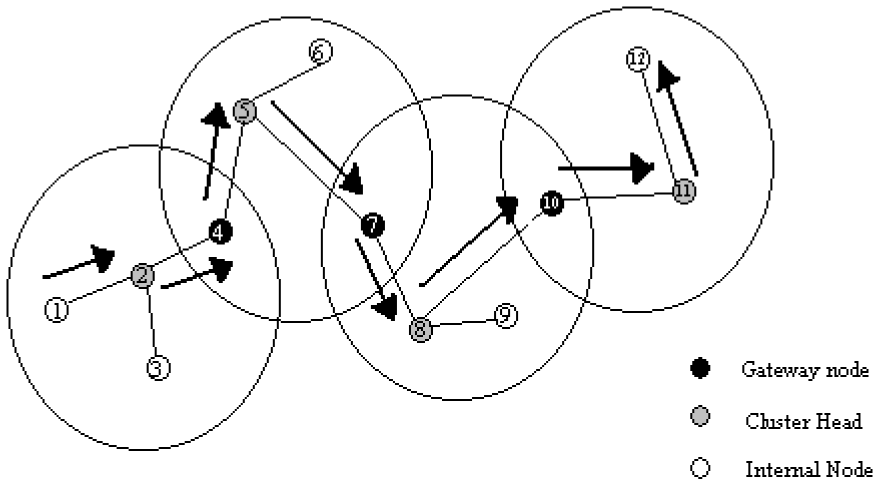

Figure 7: Cluster Gateway Switch Routing Protocol

Gateway nodes are nodes that are within the communication ranges of two or more cluster heads. A packet sent by a node is first sent to its cluster head, and then the packet is sent from the cluster head to a gateway to another cluster head, and so on until the cluster head of the destination node is reached. The packet is then transmitted to the destination from its own cluster head [12].

Table 1: Comparison of Characteristics of Table driven routing protocols

Parameters	DSDV	CGSR	WRP
Time Complexity (link addition / failure)	O(d)	O(d)	O(h)
Communication Complexity (link addition / failure)	O(x=N)	O(x=N)	O(x=N)
Routing Philosophy	Flat	Hierarchical	Flat[1]
Loop Free	Yes	Yes	Yes, but not instantaneous
Multicast Capability	No	No[2]	No
Number of Required Tables	Two	Two	Four
Frequency of Update Transmissions	Periodically & as needed	Periodically	Periodically & as needed
Updates Transmitted to	Neighbors	Neighbors & cluster head	Neighbors
Utilizes Sequence Numbers	Yes	Yes	Yes
Utilizes "Hello" Messages	Yes	No	Yes
Critical Nodes	No	Yes (cluster head)	No
Routing Metric	Shortest Path	Shortest Path	Shortest Path

N: Number of nodes in the network
D: network diameter
H: height of routing tree
Z: number of nodes affected by topological change

3.2 REACTIVE ROUTING PROTOCOLS

Reactive routing protocol is also known as on demand routing protocol. In this protocol route is discovered whenever it is needed Nodes initiate route discovery on demand basis. Source node sees its route cache for the available route from source to destination if the route is not available then it initiates route discovery process. The on- demand routing protocols have two major components [18]: for the available route from source to destination otherwise if the route is not present it initiates route discovery. The source node, in the packet, includes the destination address of the node as well address of the intermediate nodes to the destination. Route maintenance: Due to dynamic topology of the network cases of the route failure between the nodes arises due to link breakage etc, so route maintenance is done. Reactive protocols have acknowledgement mechanism due to which route maintenance is possible Reactive protocols add latency to the network due to the route discovery mechanism. Each intermediate node involved in the route discovery process adds latency. These protocols decrease the routing overhead but at the cost of increased latency in the network. Hence these protocols are suitable in the situations where low routing overhead is required. There are various well known reactive routing protocols present in MANET for example DSR, AODV, TORA and LMR [1].

3.2.1 DYNAMIC SOURCE ROUTING (DSR)

Dynamic Source Routing (DSR) is a reactive protocol based on the source route approach [19]. In Dynamic Source Routing (DSR), shown in Figure.8, the protocol is based on the link state algorithm in which source initiates route discovery on demand basis.

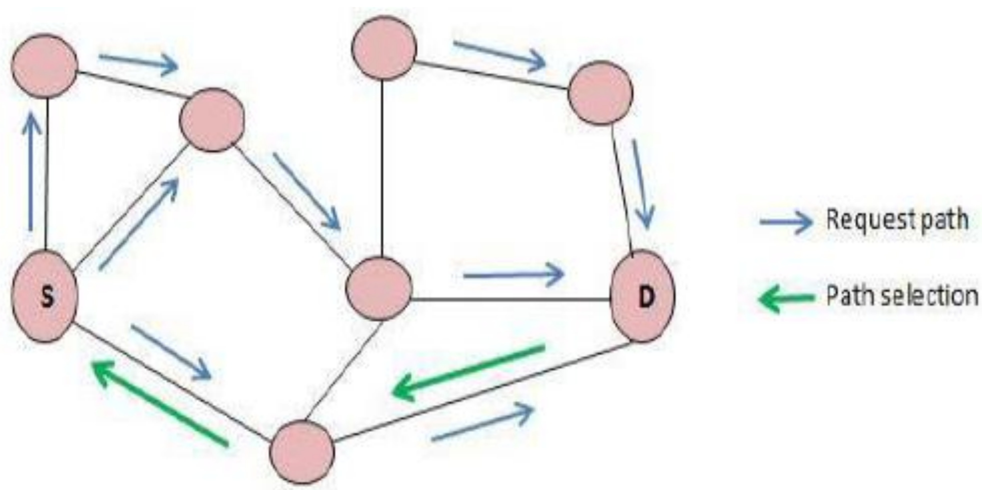

FIGURE. 8: DYNAMIC SOURCE ROUTING (DSR)

The sender determines the route from source to destination and it includes the address of intermediate nodes to the route record in the packet. DSR was designed for multi hop networks for small Diameters. It is a beaconless protocol in which no HELLO messages are exchanged between nodes to notify them of their neighbors in the network [2].

3.2.2 AD HOC ON-DEMAND DISTANCE VECTOR ROUTING (AODV)

AODV [20] is basically an improvement of DSDV. But, AODV is a reactive routing protocol instead of proactive. It minimizes the number of broadcasts by creating routes based on demand, which is not the case for DSDV. When any source node wants to send a packet to a destination, it broadcasts a route request (RREQ) packet. The neighboring nodes in turn broadcast the packet to their neighbors and the process continues until the packet reaches the destination. During the process of forwarding the route request, intermediate nodes record the address of the neighbor from which the first copy of the broadcast packet is received. This record is stored in their route tables, which helps for establishing a reverse path. If additional copies of the same RREQ are later received, these packets are discarded. The reply is sent using the reverse path. For route maintenance, when a source node moves, it can reinitiate a route discovery process. If any intermediate node moves within a particular route, the neighbor of the drifted node can detect the link failure and sends a link failure notification to its upstream neighbor. This process continues until the failure notification reaches the source node. Based on the received information, the source might decide to re-initiate the route discovery phase [12].

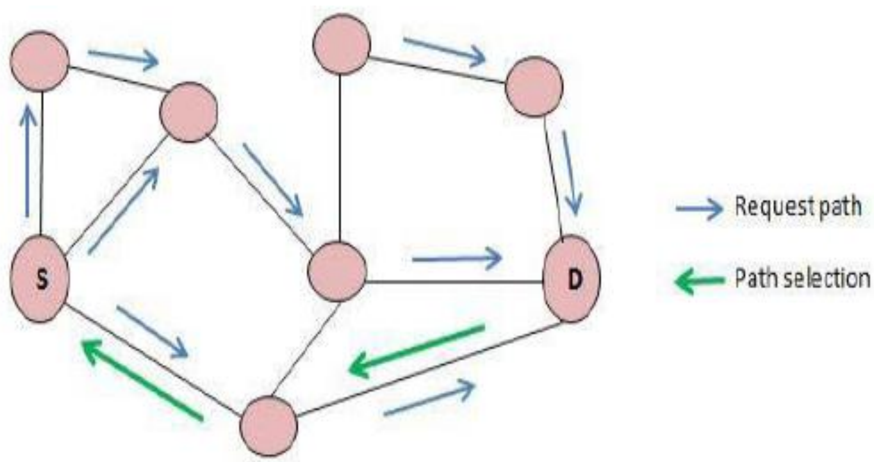

FIGURE 9 AD HOC ON-DEMAND DISTANCE VECTOR ROUTING

3.2.3 ASSOCIATIVITY-BASED ROUTING (ABR)

ABR [21] protocol defines a new type of routing metric "degree of association stability" for mobile ad hoc networks. In this routing protocol, a route is selected based on the degree of association stability of mobile nodes. Each node periodically generates beacon to announce its existence. Upon receiving the beacon message, a neighbor node updates its own associativity table. For each beacon received, the associativity tick of the receiving node with the beaconing node is increased. A high value of associativity tick for any particular beaconing node means that the node is relatively static. Associativity tick is reset when any neighboring node moves out of the neighborhood of any other node [6].

SIGNAL STABILITY–BASED ADAPTIVE ROUTING PROTOCOL (SSA)

SSA [22] protocol focuses on obtaining the most stable routes through an ad hoc network. The protocol performs on demand route discovery based on signal strength and location stability. Based on the signal strength, SSA detects weak and strong channels in the network. SSA can be divided into two cooperative protocols: the Dynamic Routing Protocol (DRP) and the Static Routing Protocol (SRP). DRP uses two tables: Signal Stability Table (SST) and Routing Table (RT). SST stores the signal strengths of the neighboring nodes obtained by periodic beacons from the link layer of each neighboring node. These signal strengths are recorded as weak or strong. DRP receives all the transmissions and, after processing, it passes those to the SRP. SRP passes the packet to the node's upper layer stack if it is the destination.

Otherwise, it looks for the destination in routing table and forwards the packet. If there is no entry in the routing table for that destination, it initiates the route-finding process. Route-request packets are forwarded to the neighbors using the strong channels. The destination, after getting the request, chooses the first arriving request packet and sends back the reply. The DRP reverses the selected route and sends a route-reply message back to the initiator of route request. The DRPs of the nodes along the path update their routing tables accordingly. In case of a link failure, the intermediate nodes send an error message to the source indicating which channel has failed. The source in turn sends an erase message to inform all nodes about the broken link and initiates a new route-search process to find a new path to the destination [12].

3.2.4 TEMPORARILY ORDERED ROUTING ALGORITHM (TORA)

TORA [23] is a reactive routing protocol with some proactive enhancements where a link between nodes is established creating a Directed Acyclic Graph (DAG) of the route from the source node to the destination. This protocol uses a link reversal model in route discovery. A route discovery query is broadcasted and propagated throughout the network until it reaches the destination or a node that has information about how to reach the destination. TORA defines a parameter, termed height. Height is a measure of the distance of the responding node's distance upto the required destination node. In the route discovery phase, this parameter is returned to the querying node.As the query response propagates back, each intermediate node updates its TORA table with the route and height to the destination node. The source node then uses the height to select the best route toward the destination. This protocol has an interesting property that it frequently chooses the most convenient route, rather than the shortest route. For all these attempts, TORA tries to minimize the routing management traffic overhead [12].

Table 2. Comparison of Characteristics of source initiated on demand Adhoc routing protocols

Performance Parameters	AODV	DSR	TORA	ABR	SSR
Time Complexity (initialization)	O(2d)	O(2d)	O(2d)	O(d+z)	O(d+z)
Time Complexity (postfailure)	O(2d)	O(2d) or 0 (cache hit)	O(2d)	O(l+z)	O(l+z)
Communication Complexity (initialization)	O(2N)	O(2N)	O(2N)	O(N+y)	O(N+y)
Communication Complexity (postfailure)	O(2N)	O(2N)	O(2x)	O(x+y)	O(x+y)
Routing Philosophy	Flat	Flat	Flat	Flat	Flat
Loop Free	Yes	Yes	Yes	Yes	Yes
Multicast Capability	Yes	No	No[3]	No	No
Beaconing Requirements	No	No	No	Yes	Yes
Multiple Route Possibilities	No	Yes	Yes	No	No
Routes Maintained in	route table	route cache	route table	route table	route table
Utilizes Route Cache/Table Expiration Timers	Yes	No	No	No	No
Route Reconfiguration Methodology	Erase Route; Notify Source	Erase Route; Notify Source	Link Reversal; Route Repair	Localized Broadcast Query	Erase Route; Notify Source
Routing Metric	Freshest & Shortest Path	Shortest Path	Shortest Path	Associativity & Shortest Path & others[4]	Associativity & Stability

Abbreviations:
d: diameter of the affected segments
y: total numbers of nodes forming the direct path where the reply packets transits
z: diameter of the directed path where the REPLY packets transits.

3.3 HYBRID ROUTING PROTOCOL

There is a trade-off between proactive and reactive protocols. Proactive protocols have large overhead and less latency while reactive protocols have less overhead and more latency. So a Hybrid protocol is presented to overcome the shortcomings of both proactive and reactive routing protocols. Hybrid routing protocol is combination of both proactive and reactive routing protocol. It uses the route discovery mechanism of reactive protocol and the table maintenance mechanism of proactive protocol so as to avoid latency and overhead problems in the network. Hybrid protocol is suitable for large networks where large numbers of nodes are present. In this large network is divided into set of zones where routing inside the zone is performed by using reactive approach and outside the zone routing is done using reactive approach. There are various popular hybrid routing protocols for MANET like ZRP, SHARP [2]

3.3.1 ZONE ROUTING PROTOCOL (ZRP)

ZRP [24] is suitable for wide variety of MANETs, especially for the networks with large span and diverse mobility patterns. In this protocol, each node proactively maintains routes within a local region, which is termed as routing zone. Route creation is done using a query-reply mechanism. For creating different zones in the network, a node first has to know who its neighbors are. A neighbor is defined as a node with whom direct communication can be established, and that is, within one hop transmission range of a node. Neighbor discovery information is used as a basis for Intra-zone Routing Protocol (IARP), which is described in detail in [25]. Rather than blind broadcasting, ZRP uses a query control mechanism to reduce route query traffic by directing query messages outward from the query source and away from covered routing zones. A covered node is a node which belongs to the routing zone of a node that has received a route query. During the forwarding of the query packet, a node identifies whether it is coming from its neighbor or not. If yes, then it marks all of its known neighboring nodes in its same zone as covered[2]. The query is thus relayed till it reaches the destination. The destination in turn sends back a reply message via the reverse path and creates the route.

3.3.2 SHARP HYBRID ADAPTIVE ROUTING PROTOCOL (SHARP)

SHARP [23] adapts between reactive and proactive routing by dynamically varying the amount of routing information shared proactively. This protocol defines the proactive zones around some nodes. The number of nodes in a particular proactive zone is determined by the node-specific zone radius. All nodes within the zone radius of a particular node become the member of that particular proactive zone for that node. If for a given destination a node is not present within a particular proactive zone, reactive routing mechanism(query-reply)is used to establish the route to that node. Proactive routing mechanism is used within the proactive zone. Nodes within the proactive zone maintain routes proactively only with respect to the central node. In this protocol, proactive zones are created automatically if some destinations are frequently addressed or sought within the network. The proactive zones act as collectors of packets, which forward the packets efficiently to the destination, once the packets reach any node at the zone vicinity [2].

4. HETEROGENEOUS WIRELESS NETWORK ARCHITECTURES

Heterogeneous networks will require the maintenance and configuration of multi-hop paths and available network interfaces due to the transient nature of the networks (relay MSs). The real challenge is to devise algorithms to discover and cope up with changing topology of the network. Consider a scenario, in a university campus where a large number of mobile users that can act as relay MSs, are spread over the campus. At noon, the users may flock towards the cafeteria and users in close proximity could form a multi-hop network. At around 2 pm, the users would leave the cafeteria and move to other parts of the campus. In such a scenario, the network topology changes with the time of the day. The issue is how to recreate and reconfigure the topology of such a dynamic network. The variety of wireless access networks in a heterogeneous environment introduces a number of challenges for connection management such as maintaining valid multi-hop paths and available network interfaces. [26]

The various architectures which have been proposed are as follows

4.1 INTEGRATED CELLULAR AD HOC RELAYING (I CAR)

The architecture proposed in [27], namely integrated cellular and ad hoc relaying (iCAR), features a typical example for MCNs with fixed relays, which makes use of the conventional cellular technology and ad hoc networking technology to realize the dynamic load balancing. The key idea of iCAR is to strategically locate a number of fixed relays, called ad hoc relay stations (ARSs), and use them to divert traffic from one possibly congested cell to other non-congested cells. Consequently, the congestion can be mitigated or even eliminated. Next, iCAR makes it possible to handle handover calls for MSs moving into a congested cell, or to accept new call requests originated from MSs in a congested cell. As shown in Figure 2. The Primary Relaying Strategy in iCAR [7].If a MS X does not find a cellular frequency channel in cell B to set up a communication link with BS B, it will send the traffic to its nearest ARS, ARS 1, using frequency bands other than the cellular band, such as the ISM band.

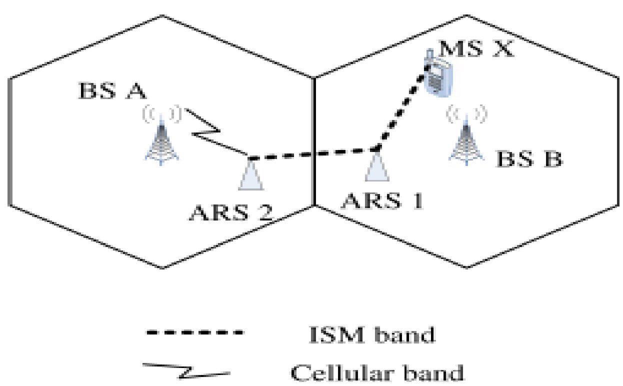

Figure 10: The Primary Relaying Strategy in iCAR

The ARS 1 will relay the traffic, using the ISM band again, to another ARS, ARS 2, in the neighboring cell, cell A. Finally, ARS 2 will forward the traffic to BS A using the cellular frequency channel. This provides a cost-effective way to overcome the congestion problem by dynamically balancing the traffic load among different cells. Besides the load balancing, iCAR is also able to extend the coverage of traditional SCNs. This is true because if a MS is out of the BSs‘coverage, it can access the system by relaying its packets through ARSs. The strategy on deploying ARSs is investigated in [28] which studied how to generate a scale -free topology for ARSs so that scalability can be achieved. Subsequently, by using the scale-free topology of ARSs, they proposed a load-balancing- based routing scheme for iCAR systems so that the system is more robust to BS failures and the available resource can be used efficiently.

4.2 MULTIHOP CELLULAR NETWORKS (MCN)

Lin and Hsu proposed multihop cellular network (MCN) [29] using multihop transmissions in the cellular networks. They pointed out two ways to construct a MCN, which are shown in Figure. 11.

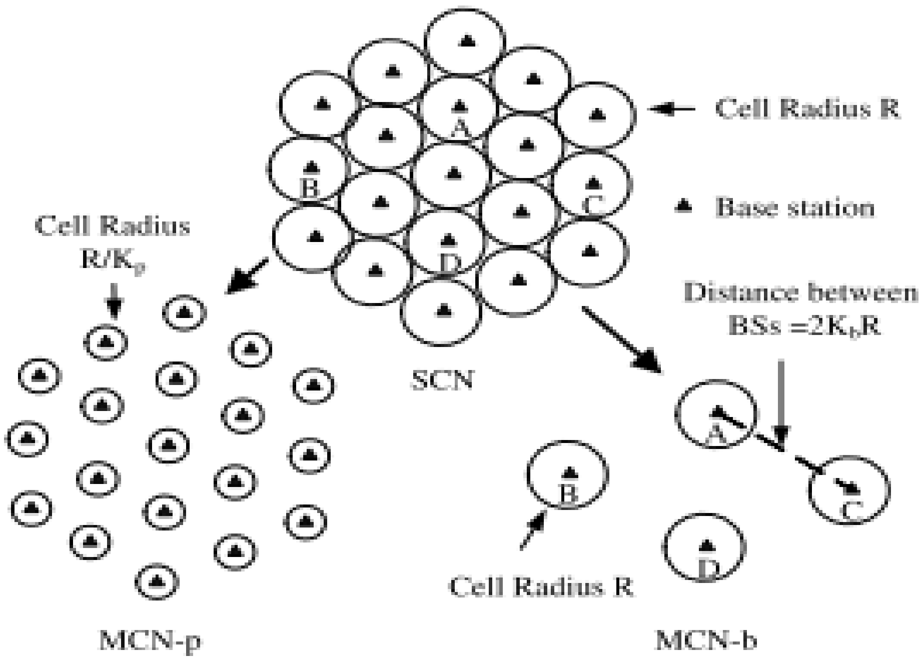

Figure 11: Two ways of Constructing MCN's

One is referred to as MCN-p, which reduces the transmission range of a BS (or MS) and keeps the same number of BSs in the service area. The other one, MCN-b, on the contrary, reduces the number of BSs such that the distance between two neighboring BSs becomes larger while keeping the transmission range of a BS or a MS. In both cases, the MS may not be able to reach the BS within one hop. Thus, multihop transmission through peer-to-peer communications among MSs, where some MSs act as mobile RSs, is necessary to communicate to the BSs. If a MS cannot communicate to a BS due to out of the transmission range, it will reach the BS via a mobile RS. However, how to select a mobile RS is not explicitly mentioned in [29]. Consequently, the network operators could use MCNs for data services with high data rate requirements and continue with SCNs, such as GSM, for traditional voice calls. Hence, MCN does not have a problem to fit into the current state of technology .In an effort to show the advantages of MCN, the authors have considered only intra-cell network traffic. However, under inter-cell traffic conditions, the benefits of spatial reuse through peer-to-peer communications, if any, and the effectiveness of the MCN architecture might be poor.

4.3 UNIFIED CELLULAR AND ADHOC NETWORKS (UCAN)

In the 3G wireless data networks, channel quality usually determines the QoS of the connection from a MS to its BS. When MS‘s are experiencing poor channel conditions this bottleneck actually limits the aggregate throughput of a cell. Thus a multihop cellular network which was proposed in [29] which has a new architecture namely Unified Cellular and Ad Hoc Network (UCAN) by opportunistically using ad hoc network such as Industry Scientific Medical (ISM) Bandwidth. As shown in Figure UCAN consists of a 3G cellular network namely CDMA 2000 Evolution-Data Only also known as High Data Rate (HDR) [30], and Wi–Fi [31] to provide high data services for any user.

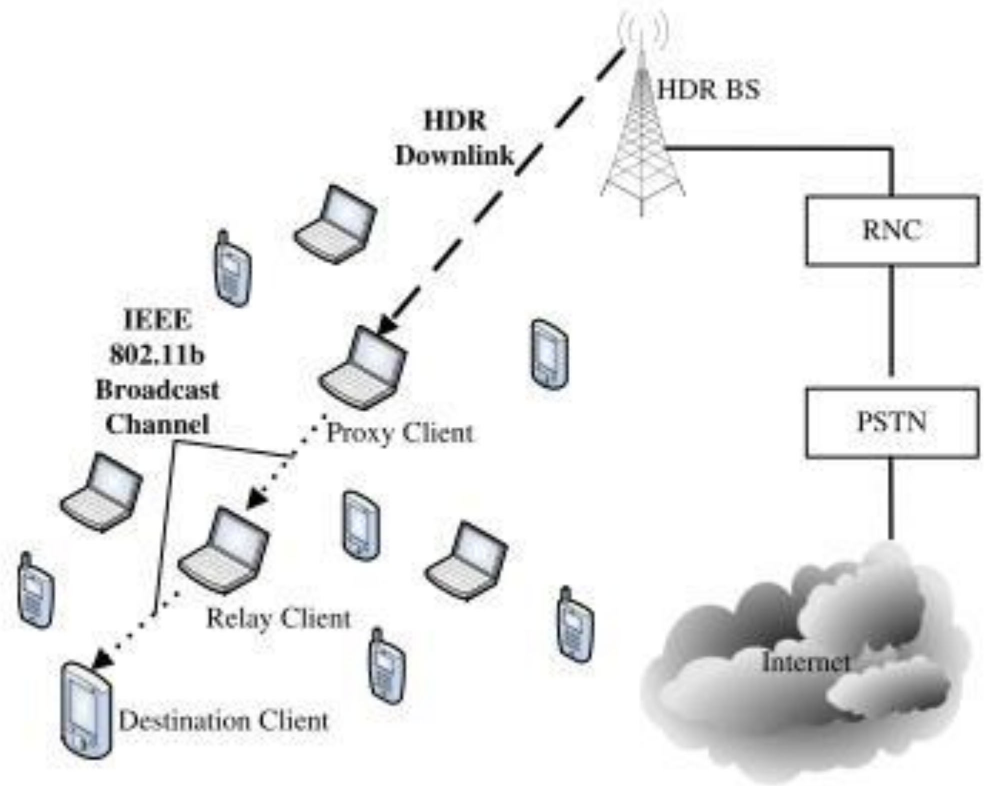

Figure 12: UCAN Architecture

If the HDR BS is not able to provide a high data rate to a specified MS, the HDR BS will forward the traffic to a proxy, a Wi –Fi terminal, which will relay the traffic to that MS. For the proxy discovery, Luo et al. proposed two algorithms greedy and on-demand proxy discovery algorithms. In general, the greedy proxy discovery protocol is proactive and the on -demand proxy discovery protocol is passive. The greedy proxy discovery requires a greedy path to reach a proxy client with high HDR downlink channel rate. A greedy path is constructed by a mobile client forwarding the route request message (RTREQ) to its neighbor client with the best HDR downlink channel rate for each hop. However, this greedy path may not always locate the proxy client with the best overall channel rate for the destination client. The on demand proxy discovery always finds the proxy client with the best channel rate at the expense of RTREQ message flooding. The drawback encountered in UCAN is the potential stability issue related to the interference in the unlicensed ISM band. Later, Feeney et al. [31] proposed a similar architecture that allows replacing a low data rate transmission with a two -hop sequence of shorter range, to provide higher data rate transmissions, using mobile relays. The difference from iCAN is that new relay proxy discovery protocols, opportunistic relay protocol (ORP), is proposed and studied in [31]. ORP allows MSs to increase their transmission data rate using a two -hop transmission with shorter transmission range in each hop, by using an intermediate MS as a relay, such that a higher data rate can be achieved with the shorter transmission range. Furthermore, ORP differs from the proxy discovery algorithms proposed in [32] in discovering proxy experimentally by opportunistically making frames available for relaying. MSs identify them as suitable relays by forwarding these frames. Lastly, a distinct feature of ORP is that it does not rely on observations of the received signal strength to infer the availability of proxy and transmit rates.

Table 3 : COMPARISON OF THE INTEGRATED ARCHITECTURES

ARCHITECTURE	WIRELESS TECHNOLOGY	RELAYING ENTITY	INTERFACE	OBJECTIVES	IMPLEMENTATIONS
iCAR	Cellular system ,WLAN	Fixed relaying Devices called ad hoc relay station (ARS)	Dual interfaces	Congestion problem by diverting the traffic from hot cell to cold cell	Using Fixed relaying devices i.e. ARS which are placed strategically in the network for relaying
MCN	Cellular system ,WLAN	Mobile station	Dual interfaces	Solving The capacity enhancement problem by reducing the number of BS's for upgrading	Reducing The transmission power of the BS and MS thus Increasing the spatial reuse of limited bandwidth
UCAN	3G Cellular system, WLAN	Mobile client	Dual interfaces	Increase s the downlink throughput of cellular system by opportunistic use of IEEE802.11 based ad hoc networks. It also maintains throughput gain fairness by refining3G BS scheduling algorithm	Relaying traffic in HDR Downlink to the proxy client, then forwarding it through several intermediate clients before Finally the Traffic arriving at the destination client. The route request message is initiated by the destination client and it also acts as a route establishment.

4.4 Multihop Cellular Networks with Hybrid Relay

MCNs with hybrid relays adopt both fixed relays and mobile relays.

4.4.1 Hierarchical Multihop Cellular Network (HMCN)

For MCNs with hybrid relays, Li et al. [33] proposed hierarchical multihop cellular network (HMCN). Additionally, a one-level version of HMCN was proposed in [34] and called cellular based multihop (CBM) system. Multihop cells are included as sub- cells in HMCN, where the multihop communication path is established through the multihop capable nodes (MHNs) as shown in Figure 13

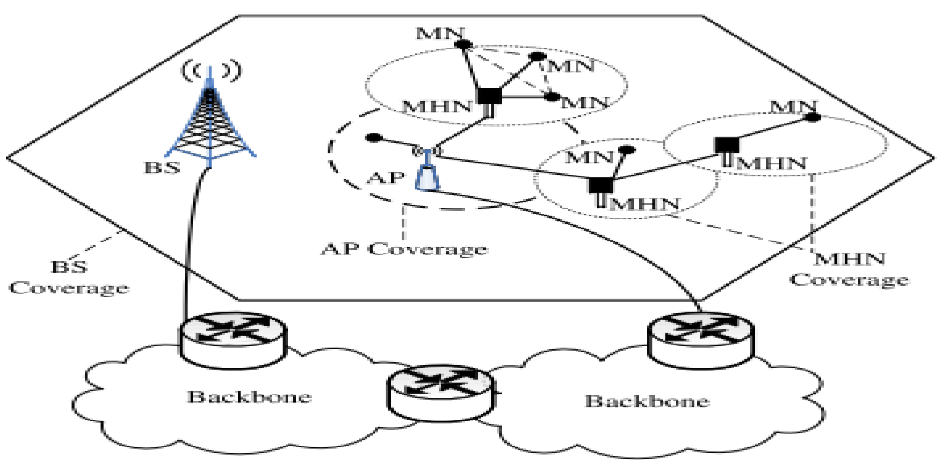

Figure 14: Cell and Multihop Cell in HMCN

Note that MHNs can be fixed relaying entities deployed by the network operator or mobile nodes (MNs) with multihop communication capability; fixed MHNs or mobile MHNs. For fixed MHNs, also called extension points (EPs), they are relaying devices deployed by the network operator at strategic locations. Fixed MHNs are comparable to the ARSs in iCAR [27], but their purpose is more related to enhance coverage of high data rate access Mobile MHNs are actually MSs with multihop communication capability. With the aid of MHNs, multihop communication is realized in Heterogeneous Networks (HN).When fixed MHNs are used, the AP-MHN link should be known in order to optimize the overall performance of HN. In addition, a fixed MHN should have additional intelligence such as full scheduling capacity and processing the forwarding data in the baseband, instead of being a simple direct repeater. Next, the locations of fixed MHNs are pre-determined and help yield the highest benefit. Routing becomes simple if the AP knows where to find a suitable MHN. Furthermore, from the view of MSs, MHNs are equivalent to simplified APs. Finally, adaptive antennas can be equipped in fixed MHNs to further improve the data rate [35].When mobile MHNs are used, a location controller is necessary to store the information of locality and neighborhood of each MS. Furthermore, each MS should be equipped with at least two sets of air interfaces, which operate in separate frequency bands. In this way, each MS can support multihop Communication. The range of multihop cell is dynamically changing. Several routing schemes were compared in [33] and it was found that routing with information provided by the cellular infrastructure would consume the lowest overhead and exhibit excellent scalability. To summarize, the several benefits offered by HN [33] include coverage extension, transmit power reduction, capacity gain, and low-cost deployment and optimized resource control. However, issues related to power control and resource management have not been investigated.

4.4.2 A-GSM & ODMA

The ad hoc global system for mobile communications (A-GSM) architecture [36] allows GSM dual-mode MSs to relay packets in MANET mode and provide connectivity in dead spot areas, thereby increasing system capacity and robustness against link failures. The dual-mode MSs are equipped with a GSM air interface and a MANET interface; when one interface is being used, the other can detect the availability of the alternative connectivity mode. The MSs have an internal unit called a dual-mode identity and internetworking unit (DIMIWU), which is responsible for performing the physical and MAC layer protocol adaptation required for each air interface (i.e., GSM or MANET A-GSM). At the link layer, A-GSM mode uses an adaptation of the GSM Link Access Protocol for D channel (LAPD m) that supports the transmission of beacon signals to advertise their capabilities of serving as relay nodes. In the beacon message, a relay node can include the BS to which it can connect, as well as the respective number of hops required to reach the BS. The drawback of this proactive gateway discovery scheme is the high control overhead. The basic idea in A-GSM is the same as in the opportunity-driven multiple access (ODMA) scheme. Both solutions integrate multiple accesses and relaying function to support multihop connections. ODMA breaks a single CDMA transmission from an MS to a BS, or vice versa, into a number of smaller radio hops by using other MSs in the same cell to relay the packets, thereby reducing the transmission power and co-channel interference. However, ODMA does not support communications for MSs outside the coverage of BSs, while A-GSM does.

4.4.3 SOPRANO-SELF-ORGANIZING PACKET RADIO

The Self Organizing Packet Radio Ad Hoc Network with Overlay (SOPRANO) [37] investigates some of the techniques by which the capacity of a cellular network can be enhanced, including bandwidth allocation, access control, routing, traffic control, and profile management. The SOPRANO architecture advocates six steps of self -organization for the physical, data link, and network layers to optimize the network capacity: neighbor discovery, connection setup, channel assignment, planning transmit/receive mode, mobility management and topology updating, and exchange of control and router information. Multi-user detection (MUD) is also suggested for the physical layer since MUD is an effective technique to reduce the excessive interference due to multihop relaying. In the MAC layer, if transmissions are directed to a node through several intermediate nodes by multihop, clever frequency channel assignments for each node can significantly reduce interference and could result in better performance. In the network layer, for enhancing system capacity, multihop routing strategy must take into account the traffic, interference, and energy consumption.

4.4.4 MOBILE ASSISTED DATA FORWARDING (MADF)

Wu et al. [38] proposed mobile-assisted data forwarding (MADF), which actually combines the characteristics of architectures proposed in iCAR [27] using fixed relays and PARCELS [39] using mobile relays. In MADF, a forwarding agent (equivalent to a relay) could be a repeater placed around the boundary of a cell or another MS. Under MADF, the cellular channels are divided into two groups fixed channels and forwarding channels, where forwarding channels will be devoted to diverting traffic from a congested cell to a non-congested cell. In this way, the system performance can be greatly improved under some delay constraint.

4.4.5 MULTIHOP RADIO ACCESS CELLULAR (MRAC) SCHEME

A similar concept is proposed by Yamao et al.[40], namely Multi-hop Radio Access Cellular (MRAC)scheme. For example, two types of hop stations (equivalent to relays) are assumed in MRAC. First is a dedicated repeater installed at a good propagation location and the other is simply a MS. However, the path diversity effect is purposely employed in MRAC, which is also studied in [41]. The path diversity is very helpful to solve problems such as AP failures, hand-off procedures and weak multihop connections

5. ISSUES IN INTEGRATING DIFFERENT TECHNOLOGIES

All the above architectures consider specific networking scenarios and have specific optimization goals such as increasing the system capacity [42, 43] and providing a good load balance [44]. A detailed comparison of these architectures can be found in [45]. MCN, ICAR, SOPRANO, ODMA, MADF and UCAN do not support MSs that are out of coverage of the BS/AP. These schemes improve the throughput between the BS/AP and the MS but do not provide extended coverage. MCN, SOPRANO and MADF assume single-mode MSs. Two-hop relay supports out of coverage MSs, but does not provide dynamic topology discovery in the event of relay MSs move away. These schemes do not consider selection of alternative routing paths based on user requirements in case multiple routing paths are available to the BS/AP. These architectures do not consider generic combinations of network architectures that support the best connectivity to the user and increase the network capacity. Also, these architectures do not take node cooperation into account and why an MS should relay packet destined to another MS? Therefore, existing inter domain multi-hop connection management protocols do not cater to the requirements of Heterogeneous Networks.

Table 4 : COMPARISON OF THE INTEGRATED ARCHITECTURES

ARCHITECTURE	WIRELESS TECHNOLOGY	RELAYING ENTITY	INTERFACE	OBJECTIVES	IMPLEMENTATIONS
HMCN	GSM, UMTS, WLAN	Multihop capable node (MHN). It can be fixed relaying devices(extension points) or mobile stations	Dual interfaces	Providing high data rate services For cellular system user through the possible use of WLAN access and high mobility Internet access for WLAN user by allowing vertical handover to cellular system	Introducing a layered architecture of several wireless systems with Overlapped coverage. Multihop communication is mostly performed in the WLAN layer
A-GSM	Cellular ,MANETs	Gateway Nodes Send beacon Messages (Proactive Scheme)	Dual Mode	Providing coverage Transmission Power reduction and capacity	The reduction in transmission power from MS away from the BS is a big advantage
MADF	Cellular ,MANETs	Ad Hoc routing protocol for routing discovery	Single mode	Load balancing Between BS‘s	Forward parts of the traffic in an overcrowded cell to some free cells.
SOPRANO	Cellular ,MANETs	Routing decision is based on minimum Interference and energy	Single mode	Base station capacity	Using different layers to optimize the network capacity, neighbor capacity , connection setup channel assignment

6. NODE COOPERATION

It is considered that all nodes existing in the network may not be trustworthy and not selfish nor having any malicious nature in them but in a real world this is not the case. The node cooperation is required for the viability of HNs. For the proper operation of a multi-hop network, the MSs are required to collaborate with each other. This collaboration or the willingness of a MS to participate in the relaying or packet forwarding process cannot be taken for granted because each user wants to maximize his or her gains, with minimal dissipation of his or her resources. The packet forwarding process consumes the battery life of the relaying MS. A selfish user may turn off his MS to avoid dissipation of resources [46, 47]. Therefore, a fundamental question is why a user would forward packet for someone else• Protocols fostering node cooperation or collaboration such as rewarding a relaying MS could encourage users to participate in packet relaying. Two important issues in developing protocols for fostering node cooperation are resource constraints of the MSs in implementing complex algorithm and additional control overhead associated with the protocol. The existing approaches for node cooperation in ad hoc networks are listed in [48]. We can see that the authors of these architectures did not show any incentive to the users as to why they should forward someone else‘s data and use their battery power consumption. Security architectures are not present in the protocols and most of them consider the network trustworthy which is not the case in a real world.

7. CONCLUSIONS

The continuous research in the field of mobile wireless communication will always give us alternatives as to how to remain connected always. Although most of the architectures have shown how to increase network capacity and increase throughput and how to reduce delay still there is more work to be done. As the future will be heterogeneous thus the mobility protocol being selected should be able to adapt to different network topologies and various possible scenarios. More incentives need to be given to the end user as to why he should be willing to help a customer located outside the cellular coverage. More security protocols also need to be introduced to enhance the effectiveness against any kind of attack by a user.

REFERENCES

[1]. C K Toh, Ad Hoc Mobile Wireless Networks, Prentice Hall Publishers , 2002
[2]. Robinpreet Kaur & Mritunjay Kumar Rai, A Novel Review on Routing Protocols in MANETs, Undergraduate Academic Research Journal (UARJ), ISSN : 2278 – 1129, Volume-1, Issue-1, 2012
[3]. Carbone, B., “Routing Protocols for Interconnecting Cellular and Ad Hoc Networks”., Universite Libre De Bruxeles , Faculte des Sciences, Department ‗d Informatique,2006‖ Tavel, P. 2007 Modeling and Simulation Design. AK Peters Ltd.
[4]. Ammar Odeh, Eman AbdelFattah and Muneer Alshowkan, Performance Evaluation Of AODV And DSR Routing Protocols In Manet Networks, International Journal of Distributed and Parallel Systems (IJDPS) Vol.3, No.4, July 2012.
[5]. George A, Kumar A, Cavalcanti D,Agrawal P D,”Protocols for mobility management in heterogeneous multihop wireless networks” published in pervasive and mobile computing 4 (2008) 92-116 Science direct.
[6]. Cavalcanti D and Agarwal D ,”Issues in Integrating Cellular Networks WLAN‘s & MANET‘s” IEEE Wireless communications 2006
[7]. Li J X, Seet C B, Chong Joo H P, 2008 “Multihop Cellular networks Technology and Economics”, Computer Networks 52 (2008) 1825–1837 www.elsevier.com/locate/comnet
[8]. Elizabeth M. Royer“A Review of Current Routing Protocols for Ad Hoc Mobile Wireless Networks” University of California, Santa Barbara Chai-Keong Toh, Georgia Institute of Technology, IEEE Personal Communications, pp. 46-55,
[9]. Krishna Gorantala , “Routing Protocols in Mobile Ad-hoc Networks”, A Master’ thesis in computer science, pp-1-36, 2006.
[10]. Perkins CE, Bhagwat P (1994) “ Highly Dynamic Destination-Sequenced Distance-Vector Routing (DSDV) for Mobile Computers”. Proceedings of ACM SIGCOMM:234–244
[11]. Cheng C, Riley R, Kumar SPR, Garcia-Luna-Aceves JJ “A Loop Free Extended Bellman-Ford Routing Protocol Without Bouncing Effect.” ACM SIGCOMM Computer Communications Review, Volume 19, Issue 4:224–236
[12]. G.Vijaya Kumar , Y.Vasudeva Reddyr , Dr.M.Nagendra , Current Research Work on Routing Protocols for MANET: A Literature Survey, International Journal on Computer Science and Engineering Vol. 02, No. 03, 2010, 706-713
[13]. Cheng C, Riley R, Kumar SPR, Garcia-Luna-Aceves JJ “A Loop Free Extended Bellman-Ford Routing Protocol Without Bouncing Effect”. ACM SIGCOMM Computer Communications Review, Volume 19, Issue 4:224–236
[14]. Perkins CE, Bhagwat P ,”Highly Dynamic Destination-Sequenced Distance-Vector Routing (DSDV) for Mobile Computers”. Proceedings of ACM SIGCOMM 234–244
[15]. Humblet PA “Another Adaptive Distributed Shortest-Path Algorithm”. IEEE Transactions on Communications, Volume 39, Issue 6:995–1003
[16]. Rajagopalan B, Faiman M “A Responsive Distributed Shortest- Path Routing Algorithm Within Autonomous Systems.” Journal of Internetworking Research and Experiment, Volume 2, Issue 1:51–69
[17]. Chiang C-C, Wu H-K, Liu W, Gerla M “Routing in Clustered Multihop, Mobile Wireless Networks with Fading Channel”. Proceedings of IEEE SICON:197–211
[18]. Tarek Sheltami and Hussein Mouftah “Comparative study of on demand and Cluster Based Routing protocols in MANETs”, IEEE conference, pp. 291-295, 2013
[19]. Johnson. D and Maltz. D. A, “Dynamic source routing in ad hoc wireless Networks” in Mobile Computing (Imielinski and H. Korth, eds.), Kluwere Academic Publishers,

[20]. Perkins CE, Royer EM, Chakeres ID (2003) Ad hoc On-Demand Distance Vector (AODV) Routing. IETF Draft, October, 2003, available at http://tools.ietf.org/html/draft-perkins- manet-aodvbis-00. Accessed 21
[21]. Toh C-K "A Novel Distributed Routing Protocol to Support Ad- Hoc Mobile Computing" .Proceedings of the IEEE 15th Annual International Phoenix Conference on Computers and Communications:480–486
[22]. Dube R, Rais CD, Wang K-Y, Tripathi SK "Signal Stability- Based Adaptive Routing (SSA) for Ad Hoc Mobile Networks" . IEEE Personal Communications, Volume 4, Issue 1:36 45
[23]. Ramasubramanian V, Haas ZJ, Sirer, EG "SHARP: A Hybrid Adaptive Routing Protocol for Mobile Ad Hoc Networks". Proceedings of ACM MobiHoc 2003:303–314
[24]. Pearlman MR, Samar P "The Zone Routing Protocol (ZRP) for Ad Hoc Networks." IETF draft, available at http://tools.ietf.org/id/draft-ietf-manetzone-zrp-04.txt. Accessed
[25]. February 2008 94 A.-S.K. Pathan and C.S. Hong Haas ZJ, Pearlman MR, Samar P "Intrazone Routing Protocol (IARP)."IETF Internet Draft, July 2002.
[26]. George A, Kumar A, Cavalcanti D, Agrawal P D, ‚‖Protocols for mobility management in heterogeneous multihop wireless networks.‖published in pervasive and mobile computing 4 (2008) 92-116 Science direct.
[27]. H. Wu, C. Qiao, S. De, O. Tonguz,. "Integrated cellular and ad hoc relaying systems: iCAR", IEEE Journal on Selected Areas in Communications 19 (10) 2105–2115.
[28]. S. Dixit, E. Yanmaz, O.K. Tonguz, , ―On the design of self-organized cellular wireless networks‖ , IEEE Communications Magazine 43 (86–93)
[29]. Y.-D. Lin, Y.-C. Hsu ― Multihop cellular: a new architecture for wireless communications‖, in: Proceedings of IEEE INFOCOM'00, Tel Aviv, Israel, , pp. 1273–1282.
[30]. IEEE Computer Society, Wireless LAN Medium Access Control(MAC) and Physical Layer (PHY) specifications: Higher-Speed Physical Layer Extension in the 2.4 GHz Band: IEEE Standard 802.11b,
[31]. L.M. Feeney, B. Cetin, D. Hollos, M. Kubisch, S. Mengesha, H. Karl, 2007 , ―Multi-rate relaying for performance improvement in IEEE 802.11 WLANs‖, in: Proceedings of WWIC'07, Coimbra, Portugal, 23–25 May,2007, pp. 201–212
[32]. H. Luo, R. Ramjee, P. Sinha, L.E. Li, S. Lu, " UCAN: a unified cellular and ad-hoc network architecture ", in: Proceedings of ACM MOBICOM', San Diego, CA, USA, 14–19 September 2003, pp. 353–367.
[33]. H. Li, M. Lott, M. Weckerle, W. Zirwas, E. Schulz,"Multihop communications in future mobile radio networks", in: Proceedings of IEEE PIMRC'02, Lisbon, Portugal, September, 2002, pp. 54–58.
[34]. H. Li, D. Yu, H. Chen, 2003,― New Approach To Multihop—Cellular Based Multihop Network‖, in: Proceedings of IEEE PIMRC'03, Beijing, China, 7–10 September 2003, pp. 1629–1633.
[35]. M. Lott, M. Weckerle, W. Zirwas, H. Li, E. Schulz, Hierarchical cellular multihop networks, in: Proceedings of the 5th European Personal Mobile CommunicationsConference, Glasgow, Scotland, UK, 22–25 April, 2003, pp. 37–43
[36]. G. Aggelou and R. Tafazolli, ―On the Relaying Capacity of Next-Generation GSM Cellular Networks,‖ IEEE Pers.Commun., vol. 8, Feb. 2011.
[37]. A. Zadeh et al., "Self-organizing Packet Radio Ad HocNetworks with Overlay (SOPRANO)," IEEE Commun. Mag., vol. 40, no pp. 149–57.
[38]. X.X. Wu, S.H.G. Chan, B. Mukherjee, B. Bhargava," MADF: mobile assisted data forwarding for wireless data networks," Journal of Communications and Networks 6 (3) 216–225
[39]. J.J. Zhou, Y.R. Yang, PARCelS: pervasive ad-hoc relaying for cellular systems, in: Proceedings of 1st Mediterranean Workshop on Ad-Hoc Networks, Sardegna, Italy, , pp. 1–6.
[40]. Y. Yamao, T. Otsu, A. Fujiwara, H. Murata, S. Yoshida, ‚― Multi-hop radio access cellular concept for fourth-generation mobile communications system‖ , in: Proceedings of IEEE PIMRC'02, Lisbon, Portugal, 15–18 September, 2002, pp. 59–63.
[41]. E. Yanmaz, O.K. Tonguz, "Dynamic load balancing and sharing performance of Integrated wireless networks" IEEE Journal on Selected Areas in Communications 22 (5) (2004) 862–872
[42]. H. Luo, R. Ramjee, R. Sicha, L. Li, S. Lu, , "UCAN: A Unified Cellular And Ad-Hoc Network Architecture" in: The Proceedings of Mobicom, September 2003.
[43]. Y. Hsu and Y. Lin, Multi-hop cellular, "A new architecture for wireless communications ―, INFOCOMM 3 (March) (2010), pp. 1273–1282
[44]. W. Hu, C. Qiao, S. De and O. Tonguz," Integrated cellular and ad hoc relaying systems: iCAR", IEEE JSAC), pp. 2105–2115
[45]. D. Cavalcanti, C.M. Cordeiro, D.P. Agrawal, B. Xie and A. Kumar,2005, ― Issues in integrating cellular networks, WLANs, and MANETs: A futuristic heterogeneous wireless network‖, IEEE Wireless Communications Magazine 12 (3) (2005), pp. 30–41.
[46]. Y. Yoo, D.P. Agrawal, "Why it pays to be selfish in MANETs•" IEEE Wireless Communications Magazine http://www.crcnetbase.com/doi/abs/10.1201/9781420046106 .ch12
[47]. Y. Yoo, S. Ahn, D.P. Agrawal, "A credit-payment scheme for packet forwarding fairness in mobile ad hoc networks" in: IEEE International Conference on Communications, ICC 2005, Seoul Korea,
[48]. N. Salem, L. Buttyan, J. Hubaux and M. Jakobsson ,," Node cooperation in hybrid ad hoc networks" IEEE Transactions on Mobile Computing 5 (4) (2006).
[49]. Sachin Dnyandeo Ubarhande, "Performance Evolution of AODV and DSR Routing Protocols in MANET Using NS2", International Journal of Scientific & Engineering Research Volume 3, Issue 5, May-2012, ISSN 2229-5518
[50]. Kaur,B., "Potential Synergy from MANET into m- Governance Environment. "National Research Paper Presentation Compitition-2010" on February 20, 2010 New Delhi.