MOBILE NETWORK LAYER

Need for Mobile IP

The IP addresses are designed to work with stationary hosts because part of the address defines the network to which the host is attached**.** A host cannot change its IP address without terminating on-going sessions and restarting them after it acquires a new address. Other link layer mobility solutions exist but are not sufficient enough for the global Internet.

Mobility is the ability of a node to change its point-of-attachment while maintaining allexisting communications and using the same IP address.
Nomadicity allows a node to move but it must terminate all existing communications and then can initiate new connections with a new address.

Mobile IP is a network layer solution for homogenous and heterogeneous mobility on the global Internet which is scalable, robust, secure and which allows nodes to maintain all ongoing communications while moving.

Design Goals: Mobile IP was developed as a means for transparently dealing with problems of mobile users. Mobile IP was designed to make the size and the frequency of required routing updates as small as possible. It was designed to make it simple to implement mobile node software. It was designed to avoid solutions that require mobile nodes to use multiple addresses.

Requirements: There are several requirements for Mobile IP to make it as a standard. Some of them are:

1. Compatibility: The whole architecture of internet is very huge and a new standard cannot introduce changes to the applications or network protocols already in use. Mobile IP is to be integrated into the existing operating systems. Also, for routers also it may be possible to enhance its capabilities to support mobility instead of changing the routers which is highly impossible. Mobile IP must not require special media or MAC/LLC protocols, so it must use the same interfaces and mechanisms to access the lower layers as IP does. Finally, end-systems enhanced with a mobile IP implementation should still be able to communicate with fixed systems without mobile IP.
2. Transparency: Mobility remains invisible for many higher layer protocols and applications. Higher layers continue to work even if the mobile computer has changed its point of attachment to the network and even notice a lower bandwidth and some interruption in the service. As many of today‘s applications have not been designed to use in mobile environments, the effects of mobility will be higher delay and lower bandwidth.
3. Scalability and efficiency: The efficiency of the network should not be affected even if a new mechanism is introduced into the internet. Enhancing IP for mobility must not generate many new messages flooding the whole network. Special care is necessary to be taken considering the lower bandwidth of wireless links. Many mobile systems

have a wireless link to an attachment point. Therefore, only some additional packets must be necessary between a mobile system and a node in the network. It is indispensable for a mobile IP to be scalable over a large number of participants in the whole internet, throughout the world.

4. Security: Mobility possesses many security problems. A minimum requirement is the authentication of all messages related to the management of mobile IP. It must be sure for the IP layer if it forwards a packet to a mobile host that this host really is the receiver of the packet. The IP layer can only guarantee that the IP address of the receiver is correct. There is no way to prevent faked IP addresses and other attacks.

The goal of a mobile IP can be summarized as: _supporting end-system mobility while maintaining scalability, efficiency, and compatibility in all respects with existing applications and Internet protocols'.

Entities and terminology

The following defines several entities and terms needed to understand mobile IP as defined in RFC 3344.

- **Mobile Node (MN):** A mobile node is an end-system or router that can change its point of attachment to the internet using mobile IP. The MN keeps its IP address and can continuously communicate with any other system in the internet as long as link-layer connectivity is given. Examples are laptop, mobile phone, router on an aircraft etc.
- **Correspondent node (CN):** At least one partner is needed for communication. In the following the CN represents this partner for the MN. The CN can be a fixed or mobile node.
- **Home network:** The home network is the subnet the MN belongs to with respect to its IP address. No mobile IP support is needed within the home network.
- **Foreign network:** The foreign network is the current subnet the MN visits and which is not the home network.
- **Foreign agent (FA):** The FA can provide several services to the MN during its visit to the foreign network. The FA can have the COA, acting as tunnel endpoint and forwarding packets to the MN. The FA can be the default router for the MN. FAs can also provide security services because they belong to the foreign network as opposed to the MN which is only visiting. FA is implemented on a router for the subnet the MN attaches to.
- **Care-of address (COA):** The COA defines the current location of the MN from an IP point of view. All IP packets sent to the MN are delivered to the COA, not directly to the IP address of the MN. Packet delivery toward the MN is done using a tunnel, i.e., the COA marks the tunnel endpoint, i.e., the address where packets exitthe tunnel. There are two different possibilities for the location of the COA: **Foreignagent COA:** The COA could be located at the FA, i.e., the COA is an IP address of the FA. The FA is the tunnel end-point and forwards packets to the MN. Many MN using the FA can share this COA as common COA.

  Co-located COA: The COA is co-located if the MN temporarily acquired an additional IP address which acts as COA. This address is now topologically correct, and the tunnel endpoint is at the MN. Co-located addresses can be acquired using services such as DHCP.

1. **Home agent (HA):** The HA provides several services for the MN and is located in the home network. The tunnel for packets toward the MN starts at the HA. The HA can be implemented on a router that is responsible for the home network. This is obviously the best position, because without optimizations to mobile IP, all packets for the MN have to go through the router anyway.
2. One disadvantage of this solution is the double crossing of the router by the packet if the MN is in a foreign network. A packet for the MN comes in via the router; the
3. Finally, a home network is not necessary at all. The HA could be again on the ‘router’ but this time only acting as a manager for MNs belonging to a virtual home network. All MNs are always in a foreign network with this solution.

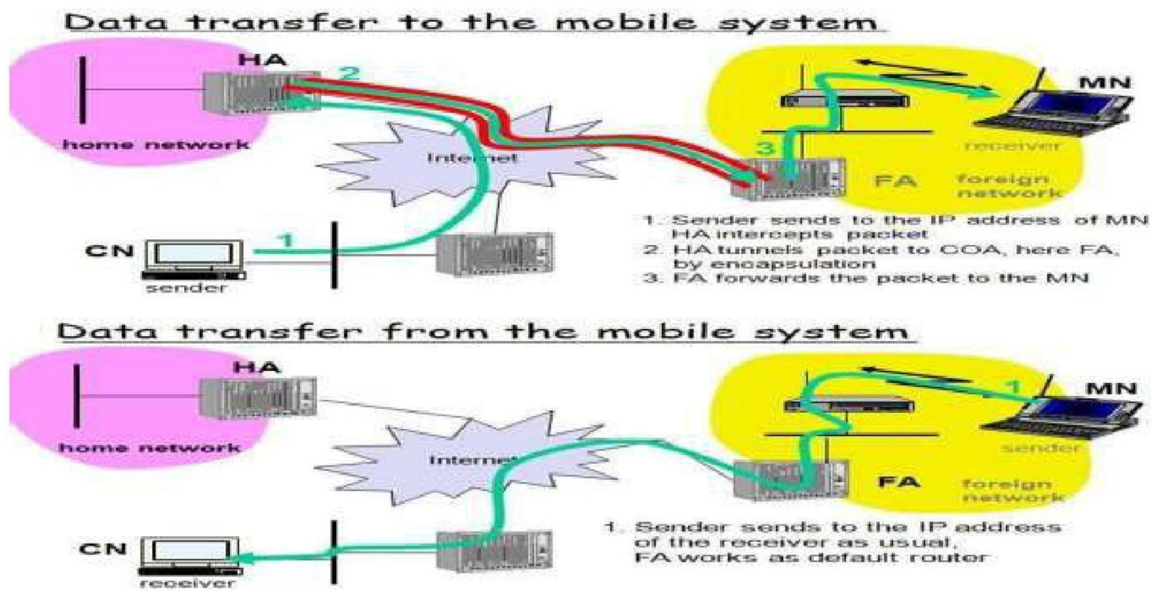
A CN is connected via a router to the internet, as are the home network and the foreign network. The HA is implemented on the router connecting the home network with the internet, an FA is implemented on the router to the foreign network. The MN is currently in the foreign network. The tunnel for packets toward the MN starts at the HA and ends at the FA, for the FA has the COA in the above example.

IP packet delivery

Consider the above example in which a correspondent node (CN) wants to send an IP packet to the MN. One of the requirements of mobile IP was to support hiding the mobility of the MN. CN does not need to know anything about the MN’s current location and sends the packet as usual to the IP address of MN as shown below.

CN sends an IP packet with MN as a destination address and CN as a source address. The internet, not having information on the current location of MN, routes the packet to the router responsible for the home network of MN. This is done using the standard routing mechanisms of the internet. The HA now intercepts the packet, knowing that MN is currently not in its home network. The packet is not forwarded into the subnet as usual, but encapsulated and tunnelled to the COA.

A new header is put in front of the old IP header showing the COA as new destination and HA as source of the encapsulated packet (step 2). The foreign agent now decapsulates the packet, i.e., removes the additional header, and forwards the original packet with CN as source and MN as destination to the MN (step 3). Again, for the MN mobility is not visible. It receives the packet with the same sender and receiver address as it would have done in the home network



Sending packets from the mobile node (MN) to the CN is comparatively simple. The MN sends the packet as usual with its own fixed IP address as source and CNs address as destination (step 4). The router with the FA acts as default router and forwards the packet inthe same way as it would do for any other node in the foreign network. As long as CN is a fixed node the remainder is in the fixed internet as usual. If CN were also a mobile node residing in a foreign network, the same mechanisms as described in steps 1 through 3 would apply now in the other direction.

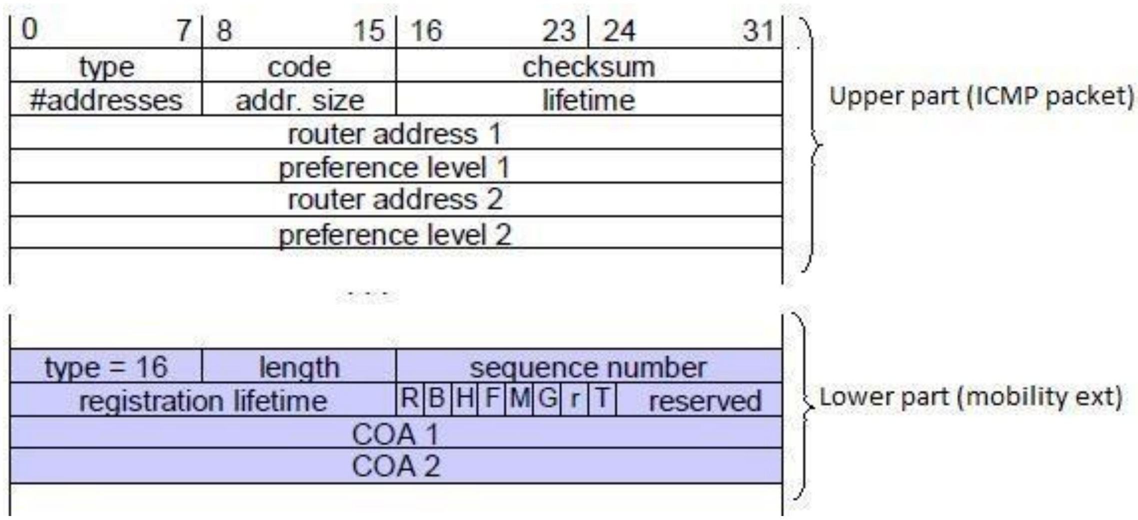
Working of Mobile IP:- Mobile IP has two addresses for a mobile host: one home address and one care- of address. The home address is permanent; the care-of address changes as the mobile host moves from one network to another. To make the change of address transparent to the rest of the Internet requires a home agent and a foreign agent. The specific function of an agent is performed in the application layer. When the mobile host and the foreign agent are the same, the care-of address is called a co-located care-of address. To communicate with a remote host, a mobile host goes through three phases: agent discovery, registration, and data transfer.

Agent Discovery

A mobile node has to find a foreign agent when it moves away from its home network. To solve this problem, mobile IP describes two methods: agent advertisement and agent solicitation.

Agent advertisement

For this method, foreign agents and home agents advertise their presence periodically using special **agent advertisement** messages, which are broadcast into the subnet. Mobile IP does not use a new packet type for agent advertisement; it uses the router advertisement packet of ICMP, and appends an agent advertisement message. The agent advertisement packet according to RFC 1256 with the extension for mobility is shown below:



The TTL field of the IP packet is set to 1 for all advertisements to avoid forwarding them. The **type** is set to 9, the **code** can be 0, if the agent also routes traffic from non-mobile nodes, or 16, if it does not route anything other than mobile traffic. The number of addresses advertised with this packet is in **#addresses** while the **addresses** themselves follow as shown. **Lifetime** denotes the length of time this advertisement is valid. **Preference** levels for each address help a node to choose the router that is the most eager one to get a new node.

The extension for mobility has the following fields defined: **type** is set to 16, **length** depends on the number of COAs provided with the message and equals 6 + 4*(number of addresses). The **sequence number** shows the total number of advertisements sent since initialization by the agent. By the **registration lifetime** the agent can specify the maximum lifetime in seconds a node can request during registration. The following bits specify the characteristics of an agent in detail.

The **R** bit (registration) shows, if a registration with this agent is required even when using a colocated COA at the MN. If the agent is currently too busy to accept new registrations it can set the **B** bit. The following two bits denote if the agent offers services as a home agent (**H**) or foreign agent (**F**) on the link where the advertisement has been sent. Bits M and G specify the method of encapsulation used for the tunnel. While IP-in-IP encapsulation is the mandatory standard, **M** can specify minimal encapsulation and **G** generic routing encapsulation. In the first version of mobile IP (RFC 2002) the **V** bit specified the use of header compression according to RFC 1144. Now the field **r** at the same bit position is set to zero and must be ignored. The new field **T** indicates that reverse tunneling is supported by the FA. The following fields contain the **COAs** advertised. A foreign agent setting the F bit must advertise at least one COA. A mobile node in a subnet can now receive agent advertisements from either its home agent or a foreign agent. This is one way for the MN to discover its location.

Agent Solicitation

If no agent advertisements are present or the inter-arrival time is too high, and an MN has not received a COA by other means, the mobile node must send **agent solicitations**. Care must be taken to ensure that these solicitation messages do not flood the network, but basically an MN can search for an FA endlessly sending out solicitation messages. If a node does not receive an answer to its solicitations it must decrease the rate of solicitations exponentially to avoid flooding the network until it reaches a maximum interval between solicitations (typically one minute). Discovering a new agent can be done anytime, not just if the MN is not connected to one.

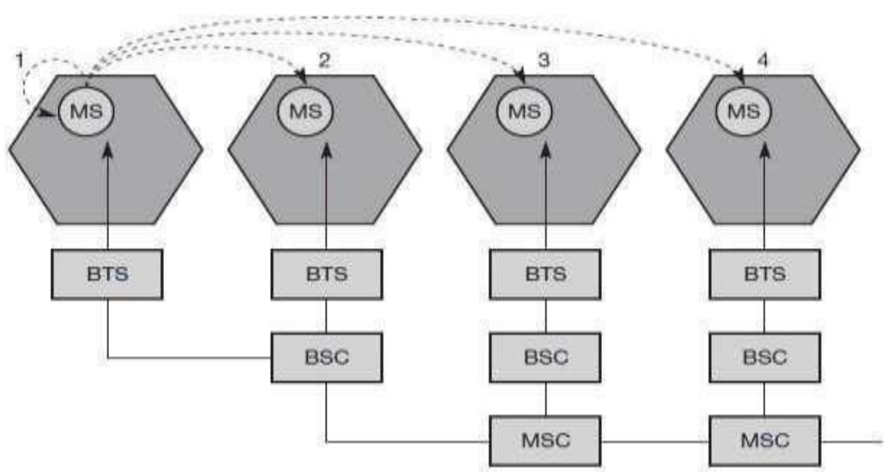
After these steps of advertisements or solicitations the MN can now receive a COA, either one for an FA or a co-located COA.

Agent Registration

Having received a COA, the MN has to register with the HA. The main purpose of the registration is to inform the HA of the current location for correct forwarding of packets.

Registration can be done in two different ways depending on the location of the COA.

- If the COA is at the FA, the MN sends its registration request containing the COA to the FA which forwards the request to the HA. The HA now sets up a **mobility binding,** ĐoŶtaiŶiŶg the ŵoďile Ŷodě s hoŵe IP addƌess aŶd the ĐuƌƌeŶt COA. It also ĐoŶtaiŶs the lifetime of the registration which is negotiated during the registration process. Registration expires automatically after the lifetime and is deleted; so, an MN should reregister before expiration. This mechanism is necessaryto avoid mobility bindings which are no longer used. After setting up the mobility binding, the HA sends a reply message back to the FA which forwards it to the MN.



- If the COA is co-located, registration can be simpler, the MN sends the request directly to the HA and vice versa. This is also the registration procedure for MNs returning to their home network to register directly with the HA.UDP packets are used for the registration requests using the port no 434. The IP source address of the packet is set to the interface address of the MN, the IP destination address is that of the FA orHA.

Registration Request

The first field **type** is set to 1 for a registration request. With the **S** bit an MN can specify if it wants the HA to retain prior mobility bindings. This allows for simultaneous bindings. Setting the **B** bit generally indicates that an MN also wants to receive the broadcast packets which have been received by the HA in the home network. If an MN uses a co-located COA, it also takes care of the decapsulation at the tunnel endpoint. The **D** bit indicates this behavior. As already defined for agent advertisements, the bits **M** and **G** denote the use of minimal encapsulation or generic routing encapsulation, respectively. **T** indicates reverse tunneling, **r** and **x** are set to zero. **Lifetime** denotes the validity of the registration in seconds. A value of zero indicates deregistration; all bits set indicates infinity. The **home address** is the fixed IP address of the MN, **home agent** is the IP address of the HA, and **COA** represents the tunnel endpoint. The 64 bit **identification** is generated by the MN to identify a request and match it with registration replies. This field is used for protection against replay attacks of registrations. The **extensions** must at least contain parameters forauthentication

A **registration reply**, which is conveyed in a UDP packet, contains a **type** fieldset to 3 and a **code** indicating the result of the registrationrequest.

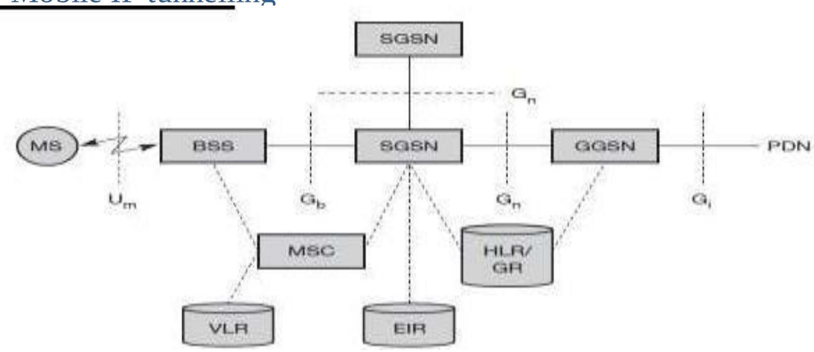
Registration Reply

The **lifetime** field indicates how many seconds the registration is valid if it was successful. **Home address** and **home agent** are the addresses of the MN and the HA, respectively. The 64-bit **identification** is used to match registration requests with replies. The value is based on the identification field from the registration and the authentication method. Again, the **extensions** must at least contain parameters for authentication.

Tunnelling and encapsulation

A **tunnel** establishes a virtual pipe for data packets between a tunnel entry and a tunnel endpoint. Packets entering a tunnel are forwarded inside the tunnel and leave thetunnel unchanged. Tunneling, i.e., sending a packet through a tunnel is achieved by using encapsulation.

Mobile IP tunnelling

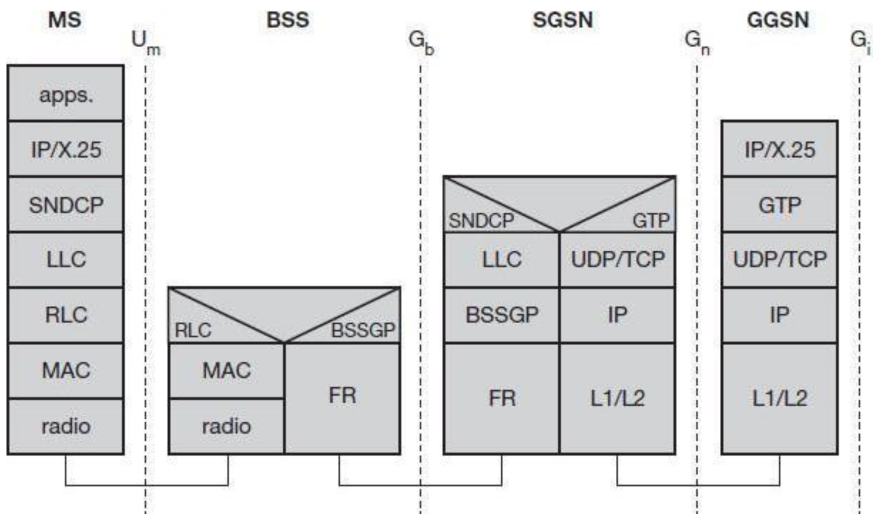


Encapsulation is the mechanism of taking a packet consisting of packet header and data and putting it into the data part of a new packet. The reverse operation, taking a packet out of the data part of another packet, is called **decapsulation**. Encapsulation and decapsulation are the operations typically performed when a packet is transferred from a higher protocol layer to a lower layer or from a lower to a higher layer respectively.

The HA takes the original packet with the MN as destination, puts it into the data part of a new packet and sets the new IP header so that the packet is routed to the COA. The new header is called outer header.

IP-in-IP encapsulation

There are different ways of performing the encapsulation needed for the tunnel between HA and COA. Mandatory for mobile IP is **IP-in-IP encapsulation** as specified in RFC 2003. The following fig shows a packet inside the tunnel.



The version field **ver** is 4 for IP version 4, the internet header length (**IHL**) denotesthe length of the outer header in 32 bit words. **DS(TOS)** is just copied from the inner header, the **length** field covers the complete encapsulated packet. The fields up to TTL have no special meaning for mobile IP and are set according to RFC 791. **TTL** must be high enough so the packet can reach the tunnel endpoint. The next field, here denoted with **IP-in-IP**, is the type of the protocol used in the IP payload. This field is set to 4, the protocol type for IPv4 because again an IPv4 packet follows after this outer header. IP **checksum** is calculated as usual. The next fields are the tunnel entry as source address (the **IP address of the HA**) and the tunnel exit point as destination address (the **COA**).

If no options follow the outer header, the inner header starts with the same fields asabove. This header remains almost unchanged during encapsulation, thus showing theoriginal sender CN and the receiver MN of the packet . The only change is TTL which is decremented by 1. This means that the whole tunnel is considered a single hop from the oƌigiŶal paĐket's poiŶt of view. This is a very important feature of tunneling as it allows theMN to behave as if it were attached to the home network. No matter how many real hops thepacket has to take in the tunnel, it is just one (logical) hop away for the MN. Finally, thepayload follows the two headers.

Minimal encapsulation

Minimal encapsulation (RFC 2004) as shown below is an optional encapsulation method for mobile IP which avoids repetitions of identical fields in IP-in-IP encapsulation. The tunnel entry point and endpoint are specified.The field for the type of the following header contains the value 55 for the minimal encapsulation protocol. The inner header is different for minimalencapsulation. The type of the following protocol and the address of the MN are needed. If the **S** bit is set, the original sender address of the CN is included as omitting the source is quite often not an option. No field for fragmentation offset is left in the inner header and minimal encapsulation does not work with already fragmented packets.

Generic Routing Encapsulation

Unlike IP-in-IP and Minimal encapsulation which work only for IP packets, **Generic routing encapsulation** (GRE) allows the encapsulation of packets of one protocol suite into the payload portion of a packet of another protocol suite as shown below. The packet of one protocol suite with the original packet header and data is taken and a new GRE header is prepended. Together this forms the new data part of the new packet. Finally, the header of the second protocol suite is put in front.The following figure shows the fields of a packet inside the tunnel between HA and COA using GRE as an encapsulation scheme according to RFC 1701. The outer header is the standard IP header with HA as source address and COA as destination address. The protocol type used in this outer IP header is 47 for GRE.

The GRE header starts with several flags indicating if certain fields are present or not. A minimal GRE header uses only 4 bytes. The **C** bit indicates if the checksum field is present and contains valid information. If **C** is set, the **checksum** field contains a valid IP checksum of the GRE header and the payload. The **R** bit indicates if the offset and routing fields are present and contain valid information. The **offset** represents the offset in bytes for the first source **routing** entry. The routing field, if present, has a variable length and contains fields for source routing. GRE also offers a **key** field which may be used for authentication. If this field is present, the **K** bit is set. The sequence number bit **S** indicates if the **sequence** number field is present, if the s bit is set, strict source routing is used.

The **recursion control** field (rec.) is an important field that additionally distinguishes GRE from IP-in-IP and minimal encapsulation. This field represents a counter that shows the number of allowed recursive encapsulations. The default value of this field should be 0, thus allowing only one level of encapsulation. The following **reserved** fields must be zero and are ignored on reception. The **version** field contains 0 for the GRE version. The following 2 byte **protocol** field represents the protocol of the packet following the GRE header. The standard header of the original packet follows with the source address of the correspondent node and the destination address of the mobile node.

A simplified header of GRE following RFC 2784 is shown below.

The field **C** indicates again if a checksum is present. The next 5 bits are set to zero, then 7 reserved bits follow. The **version** field contains the value zero. The **protocol** type, again, defines the protocol of the payload following RFC 3232. If the flag C is set, then **checksum** field and a field called reserved1 follows. The latter field is constant zero set to zero follow.

Optimizations

If a scenario occurs, where if the MN is in the same subnetwork as the node to which it is communicating and HA is on the other side of the world. It is called triangular routing problem as it causes unnecessary overheads for the network between CN and the HA.

A solution to this problem is to inform the CN of the current location of the MN. The CN canlearn the location by caching it in a binding cache, which is a part of the routing table for the CN. HA informs the CN of the location. It needs four additional messages:

- **Binding Request**: It is sent by the node that wants to know the current location of an MN to the HA. HA checks if it is allowed to reveal the location and then sends back a binding update
- **Binding update:** It is sent by the HA to the CN revealing the current location of an MN. It contain the fixed IP address of the MN and the COA. This message can request anacknowledgement.
- **Binding acknowledgement**: If requested, a node returns this acknowledgement after receiving a binding update message
- **Binding warning:** A node sends a binding warning if it decapsulates a packet for an MN, ďut it is Ŷote the ĐuƌƌeŶt FA of this MN . It ĐoŶtaiŶs MNs̛ hoŵe addƌess aŶd a target nodes address. The recipient can be the HA, so the HA now sends a binding update to thenode that obviously has a wrong COA for the MN.

The following figure shows how the four additional messages are used together if an MN changes its FA. The CN can request the current location from the HA. If allowed by the MN, the HA returns the COA of the MN via an update message. The CN acknowledges this updatemessage and stores the mobility binding. Now the CN can send its data directly to the current foreign agent FAold. FAold forwards the packets to the MN. This scenario shows a COA located at an FA. Encapsulation of data for tunneling to the COA is now done by the CN, not the HA.

The MN might now change its location and register with a new foreign agent , FAnew.This registration is also forwarded to the HA to update its location database . Furthermore, FAnew informs FAold aďout the Ŷeǁ ƌegistƌatioŶ of MN . MNs̛ ƌegistƌatioŶ ŵessage contains the address of FAold for this purpose. Passing this information is achieved via an update message, which is acknowledged by FAold.

Without the information provided by the new FA, the old FA would not get to know anything about the new location of MN. In this case, CN does not know anything about the new location, so it still tunnels its packets for MN to the old FA, FAold. This FA now notices packets with destination MN, but also knows that it is not the current FA of MN. FAold might now forward these packets to the new COA of MN which is FAnew in this example. This forwarding of packets is another optimization of the basic Mobile IP providing **smooth handovers**. Without this optimization, all packets in transit would be lost while the MN moves from one FA to another.

To tell CN that it has a stale binding cache, FAold sends, a binding warning message to CN. CN then requests a binding update. (The warning could also be directly sent to the HAtriggering an update). The HA sends an update to inform the CN about the new location, which is acknowledged. Now CN can send its packets directly to FAnew, again avoiding triangular routing. Unfortunately, this optimization of mobile IP to avoid triangular routing causes several security problems

Reverse Tunnelling

The reverse path from MS to the CN looks quite simple as the MN can directly send its packets to the CN as in any other standard IP situation. The destination address in the packets is that of CN. But it has some problems explained below:-

Quite often firewalls are designed to only allow packets with topologically correct addresses to pass to provide simple protection against misconfigured systems of unknown addresses. However, MN still sends packets with its fixed IP address as source which is not topologically correct in a foreign network. Firewalls often filter packets coming from outside containing a source address from computers of the internal network. This also implies that an MN cannot send a packet to a computer residing in its home network.

While the nodes in the home network might participate in a multi-cast group, an MN in a foreign network cannot transmit multi-cast packets in a way that they emanate from its home network without a reverse tunnel. The foreign network might not even provide the technical infrastructure for multi-cast communication (multi-cast backbone, Mbone).

- If the MN moves to a new foreign network, the older TTL might be too low for the packets to reach the same destination nodes as before. Mobile IP is no longer transparent if a user has to adjust the TTL while moving. A reverse tunnel is needed that represents only one hop, no matter how many hops are really needed from the foreign to the home network

Based on the above considerations, reverse tunnelling is defined as an extension to mobile IP (per RFC 2344). It was designed backward compatible to mobile IP and defines topologically correct reverse tunnelling to handle the above stated problems.

Packet Forwarding **Reverse Tunnel**

Reverse tunneling does not solve

- problems with firewalls, the reverse tunnel can be abused to circumvent security mechanisms (tunnel hijacking)
- optimization of data paths, i.e. packets will be forwarded through the tunnel via the HAto a sender (double triangular routing)

IPv6

The design of Mobile IP support in IPv6 (Mobile IPv6) benefits both from the experiences gained from the development of Mobile IP support in IPv4, and from the opportunities provided by IPv6. Mobile IPv6 thus shares many features with Mobile IPv4, but is integrated into IPv6 and offers many other improvements. This section summarizes the major differences between Mobile IPv4 and Mobile IPv6:

- There is no need to deploy special routers as "foreign agents", as in Mobile IPv4. MobileIPv6 operates in any location without any special support required from the local router.
- Support for route optimization is a fundamental part of the protocol, rather than a nonstandard set of extensions.
- Mobile IPv6 route optimization can operate securely even without pre-arranged security associations. It is expected that route optimization can be deployed on a global scale between all mobile nodes and correspondent nodes.
- Support is also integrated into Mobile IPv6 for allowing route optimization to coexist efficiently with routers that perform "ingressfiltering"
- The IPv6 Neighbor Unreachability Detection assures symmetric reachability between the mobile node and its default router in the current location.

Most packets sent to a mobile node while away from home in Mobile IPv6 are sent using an IPv6 routing header rather than IP encapsulation, reducing the amount of resulting overhead compared to Mobile IPv4.

- Mobile IPv6 is decoupled from any particular link layer, as it uses IPv6 Neighbor Discovery instead of ARP. This also improves the robustness of the protocol.
- The use of IPv6 encapsulation (and the routing header) removes the need in Mobile IPv6 to manage "tunnel soft state".
- The dynamic home agent address discovery mechanism in Mobile IPv6 returns a single reply to the mobile node. The directed broadcast approach used in IPv4 returns separate replies from each home agent.

Dynamic Host Configuration Protocol (DHCP)

DHCP is an automatic configuration protocol used on IP networks. **DHCP** allows a computer to join an IP-based network without having a pre-configured IP address. DHCP is a protocol that assigns unique IP addresses to devices, then releases and renews these addresses as devices leave and re-join the network. If a new computer is connected to a network, DHCP can provide it with all the necessary information for full system integration into the network, e.g., addresses of a DNS server and the default router, the subnet mask, the domain name, and an IP address. Providing an IP address makes DHCP very attractive for mobile IP as a source of care-of-addresses.

DHCP is based on a client/server model as shown below. DHCP clients send a request to a server (DHCPDISCOVER in the example) to which the server responds. A client sends requests using MAC broadcasts to reach all devices in the LAN. A DHCP relay might be needed to forward requests across inter-working units to a DHCPserver.

Consider the scenario where there is one client and two servers are present. A typical initialization of a DHCP client is shown below:

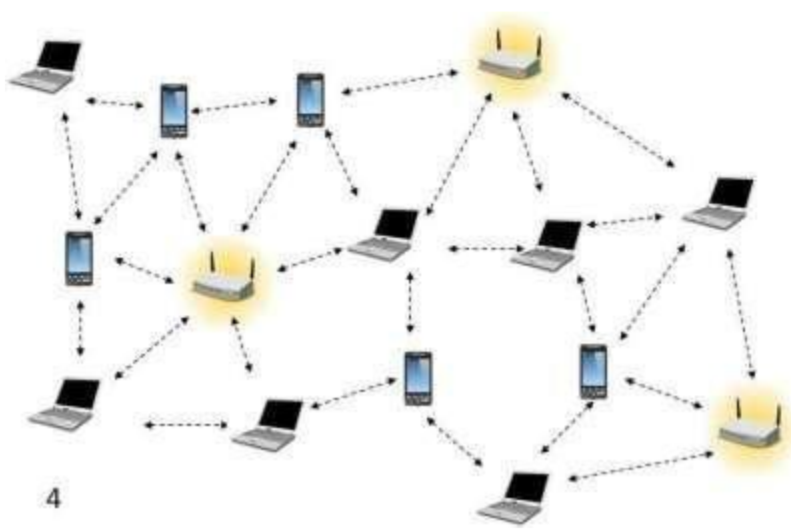
the client broadcasts a DHCPDISCOVER into the subnet. There might be a relay to forwardthis broadcast. In the case shown, two servers receive this broadcast and determine the configuration they can offer to the client. Servers reply to the ĐlieŶt̓s ƌeƋuest with DHCPOFFER and offer a list of configuration parameters. The client can now choose one ofthe configurations offered. The client in turn replies to the servers, accepting one of theconfigurations and rejecting the others using DHCPREQUEST. If a server receives aDHCPREQUEST with a rejection, it can free the reserved configuration for other possibleclients. The server with the configuration accepted by the client now confirms theconfiguration with DHCPACK. This completes the initialization phase. If a client leaves asubnet, it should release the configuration received by the server using DHCPRELEASE.Now the server can free the context stored for the client and offer the configuration again.

The configuration a client gets from a server is only leased for a certain amount of time, it has to be reconfirmed from time to time. Otherwise the server will free the configuration. This timeout of configuration helps in the case of crashed nodes or nodes moved away without releasing the context.

DHCP is a good candidate for supporting the acquisition of care-of addresses for mobile nodes. The same holds for all other parameters needed, such as addresses of the default router, DNS servers, the timeserver etc. A DHCP server should be located in the subnet of the access point of the mobile node, or at least a DHCP relay should provide forwarding of the messages. RFC 3118 specifies authentication for DHCP messages so as to provide protection from malicious DHCP servers. Without authentication, a DHCP server cannot trust the mobile node and vice versa.

Mobile Ad Hoc Networks (MANETs)

Mobile Ad hoc NETworks (MANETs) are wireless networks which are characterized by dynamic topologies and no fixed infrastructure. Each node in a MANET is a computer that may be required to act as both a host and a router and, as much, may be required to forward packets between nodes which cannot directly communicate with one another. Each MANET node has much smaller frequency spectrum requirements that that for a node in a fixed infrastructure network. A MANET is an autonomous collection of mobile users that communicate over relatively bandwidth constrained wireless links. Since the nodes are mobile, the network topology may change rapidly and unpredictably over time. The network is decentralized, where all network activity including discovering the topology and delivering messages must be executed by the nodes themselves, i.e., routing functionality will be incorporated into mobile nodes.



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A mobile ad hoc network is a collection of wireless nodes that can dynamically be set up anywhere and anytime without using any pre-existing fixed network infrastructure.

MANET- Characteristics

- Dynamic network topology
- Bandwidth constraints and variable link capacity
- Energy constrained nodes
- Multi-hop communications
- Limited security
- Autonomous terminal
- Distributed operation
- Light-weight terminals

Need for Ad Hoc Networks

- Setting up of fixed access points and backbone infrastructure is not always viable
  – Infrastructure may not be present in a disaster area or war zone
  – Infrastructure may not be practical for short-range radios; Bluetooth (range ~ 10m)
- Ad hoc networks:
  – Do not need backbone infrastructure support
  – Are easy to deploy
  – Useful when infrastructure is absent, destroyed or impractical

Properties of MANETs

- MANET enables fast establishment of networks. When anew network is to be established, the only requirement is to provide a new set of nodes with limited wireless communication range. A node has limited capability, that is, it can connect only to the nodes which are nearby. Hence it consumes limited power.
- A MANET node has the ability to discover a neighboring node and service. Using a service discovery protocol, a node discovers the service of a nearby node and communicates to a remote node in the MANET.
- MANET nodes have peer-to-peer connectivity among themselves.
- MANET nodes have independent computational, switching (or routing), and communicationcapabilities.
- The wireless connectivity range in MANETs includes only nearest node connectivity.
- The failure of an intermediate node results in greater latency in communicating with theremote server.
- Limited bandwidth available between two intermediate nodes becomes a constraint for the MANET. The node may have limited power and thus computations need to be energy-efficient.
- There is no access-point requirement in MANET. Only selected access points are providedfor connection to other networks or other MANETs.
- MANET nodes can be the iPods, Palm handheld computers, Smartphones, PCs, smart labels,smart sensors, and automobile-embedded systems\
- MANET nodes can use different protocols, for example, IrDA, Bluetooth, ZigBee, 802.11,GSM, and TCP/IP.MANET node performs data caching, saving, andaggregation.
- MANET mobile device nodes interact seamlessly when they move with the nearby wireless nodes, sensor nodes, and embedded devices in automobiles so that the seamless connectivity is maintained between the devices.

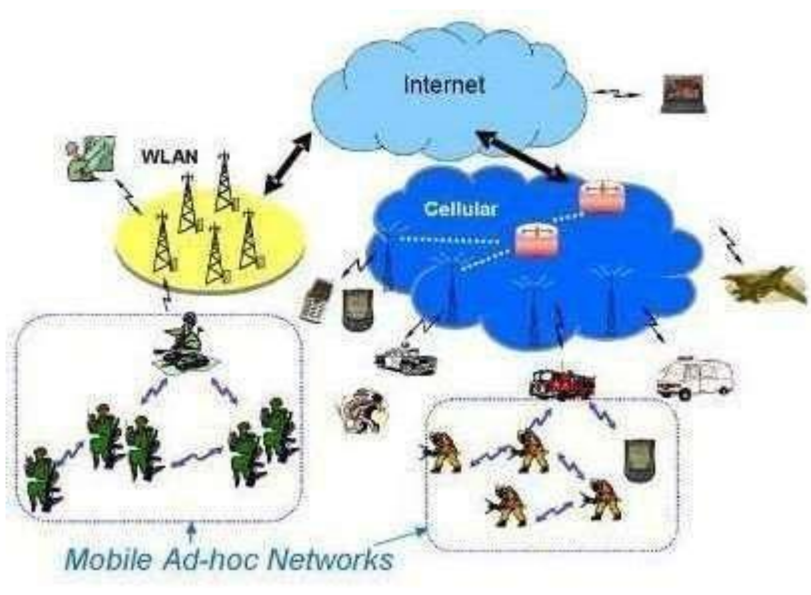
MANET challenges

To design a good wireless ad hoc network, various challenges have to be taken into account:

- Dynamic Topology: Nodes are free to move in an arbitrary fashion resulting in the topologychanging arbitrarily. This characteristic demands dynamic configuration of the network.
- Limited security: Wireless networks are vulnerable to attack. Mobile ad hoc networks aremore vulnerable as by design any node should be able to join or leave the network at any time. This requires flexibility and higher openness.
- Limited Bandwidth: Wireless networks in general are bandwidth limited. In an ad hoc network, it is all the more so because there is no backbone to handle or multiplex higher bandwidth
- Routing: Routing in a mobile ad hoc network is complex. This depends on many factors, including finding the routing path, selection of routers, topology, protocol etc.

Applications of MANETS

The set of applications for MANETs is diverse, ranging from small, static networks that are constrained by power sources, to large-scale, mobile, highly dynamic networks. The design of network protocols for these networks is a complex issue. Regardless of the application, MANETs need efficient distributed algorithms to determine network organization, link scheduling, and routing. –oŵe of the ŵaiŶ appliĐatioŶ aƌeas of MANETs͛ are:



- **Military battlefield**– soldiers, tanks, planes. Ad- hoc networking would allow the military to take advantage of commonplace network technology to maintain an information network between the soldiers, vehicles, and military information headquarters.
- **Sensor networks** – to monitor environmental conditions over a large area
- **Local level** – Ad hoc networks can autonomously link an instant and temporary multimedia network using notebook computers or palmtop computers to spread and share information among participants at e.g. conference or classroom. Another appropriate local level application might be in home networks where devices can communicate directly to

exchange information.

- **Personal Area Network (PAN**) – pervasive computing i.e. to provide flexible connectivity between personal electronic devices or home appliances. Short-range MANET can simplify the intercommunication between various mobile devices (such as a PDA, a laptop, and a cellular phone). Tedious wired cables are replaced with wireless connections. Such an ad hoc network can also extend the access to the Internet or other networks by mechanisms e.g. Wireless LAN (WLAN), GPRS, and UMTS.
- **Vehicular Ad hoc Networks** – intelligent transportation i.e. to enable real time vehiclemonitoring and adaptive traffic control
- **Civilian environments** – taxi cab network, meeting rooms, sports stadiums, boats, small aircraft
- **Emergency operations** – search and rescue, policing and fire fighting and to provide connectivity between distant devices where the network infrastructure is unavailable. Ad hoc can be used in emergency/rescue operations for disaster relief efforts, e.g. in fire, flood, or earthquake. Emergency rescue operations must take place where non-existing or damaged communications infrastructure and rapid deployment of a communication network is needed. Information is relayed from one rescue team member to another over a small hand held.

Routing in MANET's

Routing in Mobile Ad hoc networks is an important issue as these networks do not have fixed infrastructure and routing requires distributed and cooperative actions from all nodes in the network. MANET's provide point to point routing similar to Internet routing. The major difference

between routing in MANET and regular internet is the route discovery mechanism. Internetrouting protocols such as RIP or OSPF have relatively long converge times, which is acceptablefor a wired network that has infrequent topology changes. However, a MANET has a rapidtopology changes due to node mobility making the traditional internet routing protocolsinappropriate. MANET-specific routing protocols have been proposed, that handle topologychanges well, but they have large control overhead and are not scalable for large networks.Another major difference in the routing is the network address. In internet routing, the networkaddress (IP address) is hierarchical containing a network ID and a computer ID on that network.In contrast, for most MANET's the network address is simply an ID of the node in the network and is not hierarchical. The routing protocol must use the entire address to decide the next hop.

Some of the fundamental differences between wired networks & ad-hoc networks are:

- Asymmetric links: - Routing information collected for one direction is of no use for the other direction. Many routing algorithms for wired networks rely on a symmetric scenario.
- Redundant links: - In wired networks, some redundancy is present to survive link failures and this redundancy is controlled by a network administrator. In ad-hoc networks, nobody controls redundancy resulting in many redundant links up to the extreme of a complete meshed topology.
- Interference: - In wired networks, links exist only where a wire exists, and connections are planned by network administrators. But, in ad-hoc networks links come and go depending on transmission characteristics, one transmission might interfere with another and nodes might

overhear the transmission of other nodes.

- Dynamic topology: - The mobile nodes might move in an arbitrary manner or medium characteristics might change. This result in frequent changes in topology, so snapshots are valid only for a very short period of time. So, in ad-hoc networks, routing tables must somehow reflect these frequent changes in topology and routing algorithms have to be adopted.

Summary of the difficulties faced for routing in ad-hoc networks

- Traditional routing algorithms known from wired networks will not work efficiently or fail completely. These algorithms have not been designed with a highly dynamic topology, asymmetric links, or interference in mind.
- Routing in wireless ad-hoc networks cannot rely on layer three knowledge alone. Information from lower layers concerning connectivity or interference can help routing algorithms to find a good path.
- Centralized approaches will not really work, because it takes too long to collect the current status and disseminate it again. Within this time the topology has already changed.
- Many nodes need routing capabilities. While there might be some without, at least one router has to be within the range of each node. Algorithms have to consider the limited battery power of these nodes.
- The notion of a connection with certain characteristics cannot work properly. Ad-hoc networks will be connectionless, because it is not possible to maintain a connection in a fast changing environment and to forward data following this connection. Nodes have to make local decisions for forwarding and send packets roughly toward the final destination.
- A last alternative to forward a packet across an unknown topology is flooding. This approach always works if the load is low, but it is very inefficient. A hop counter is needed in each packet to avoid looping, and the diameter of the ad-hoc network.

Types of MANET Routing Algorithms:

1. Based on the information used to build routing tables :
   - Shortest distance algorithms: algorithms that use distance information to build routing tables.
   - Link state algorithms: algorithms that use connectivity information to build a topology graph that is used to build routing tables.

2. Based on when routing tables are built:
   - Proactive algorithms: maintain routes to destinations even if they are not needed. Some of the examples are Destination Sequenced Distance Vector (DSDV), Wireless Routing Algorithm (WRP), Global State Routing (GSR), Source-tree Adaptive Routing (STAR), Cluster-Head Gateway Switch Routing (CGSR), Topology Broadcast Reverse Path Forwarding (TBRPF), Optimized Link State Routing (OLSR) etc.
     - Always maintain routes:- Little or no delay for route determination
     - Consume bandwidth to keep routes up-to-date

- Maintain routes which may never be used
- Advantages: low route latency, State information, QoS guarantee related to connection set-up or other real-time requirements
- Disadvantages: high overhead (periodic updates) and route repair depends on update frequency

- Reactive algorithms: maintain routes to destinations only when they are needed. Examples are Dynamic Source Routing (DSR), Ad hoc-On demand distance Vector (AODV), Temporally ordered Routing Algorithm (TORA), Associativity-Based Routing (ABR) etc
  - only obtain route information when needed
  - Advantages: no overhead from periodic update, scalability as long as there isonly light traffic and low mobility.
  - Disadvantages: high route latency, route caching can reduce latency

- Hybrid algorithms: maintain routes to nearby nodes even if they are not needed and maintain routes to far away nodes only when needed. Example is Zone Routing Protocol (ZRP).

Which approach achieves a better trade-off depends on the traffic and mobilitypatterns.

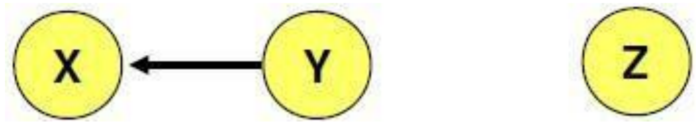
Destination sequence distance vector (DSDV)

Destination sequence distance vector (DSDV) routing is an example of proactive algorithms and an enhancement to distance vector routing for ad-hoc networks. Distance vector routing is used as routing information protocol (RIP) in wired networks. It performs extremely poorly with certain network changes due to the count-to-infinity problem. Each node exchanges its neighbor table periodically with its neighbors. Changes at one node in the network propagate slowly through the network. The strategies to avoid this problem which are used in fixed networks do not help in the case of wireless ad-hoc networks, due to the rapidly changing topology. This might create loops or unreachable regions within thenetwork.

DSDV adds the concept of sequence numbers to the distance vector algorithm. Each routing advertisement comes with a sequence number. Within ad-hoc networks, advertisements may propagate along many paths. Sequence numbers help to apply the advertisements in correct order. This avoids the loops that are likely with the unchanged distance vector algorithm.

Each node maintains a routing table which stores next hop, cost metric towards each destination and a sequence number that is created by the destination itself. Each node periodically forwards routing table to neighbors. Each node increments and appends its sequence number when sending its local routing table. Each route is tagged with a sequence number; routes with greater sequence numbers are preferred. Each node advertises a monotonically increasing even sequence number for itself. When a node decides that a route is broken, it increments the sequence number of the route and advertises it with infinite metric. Destination advertises new sequence number.

When X receives information from Y about a route to Z,



- Let destination sequence number for Z at X be S(X), S(Y) is sent from Y
- If S(X) > S(Y), then X ignores the routing information received from Y
- If S(X) = S(Y), and cost of going through Y is smaller than the route known to X, then Xsets Y as the next hop to Z
- If S(X) < S(Y), then X sets Y as the next hop to Z, and S(X) is updated to equal S(Y)

Besides being loop-free at all times, DSDV has low memory requirements and a quick convergence via triggered updates. Disadvantages of DSDV are, large routing overhead, usage of only bidirectional links and suffers from count to infinity problem.

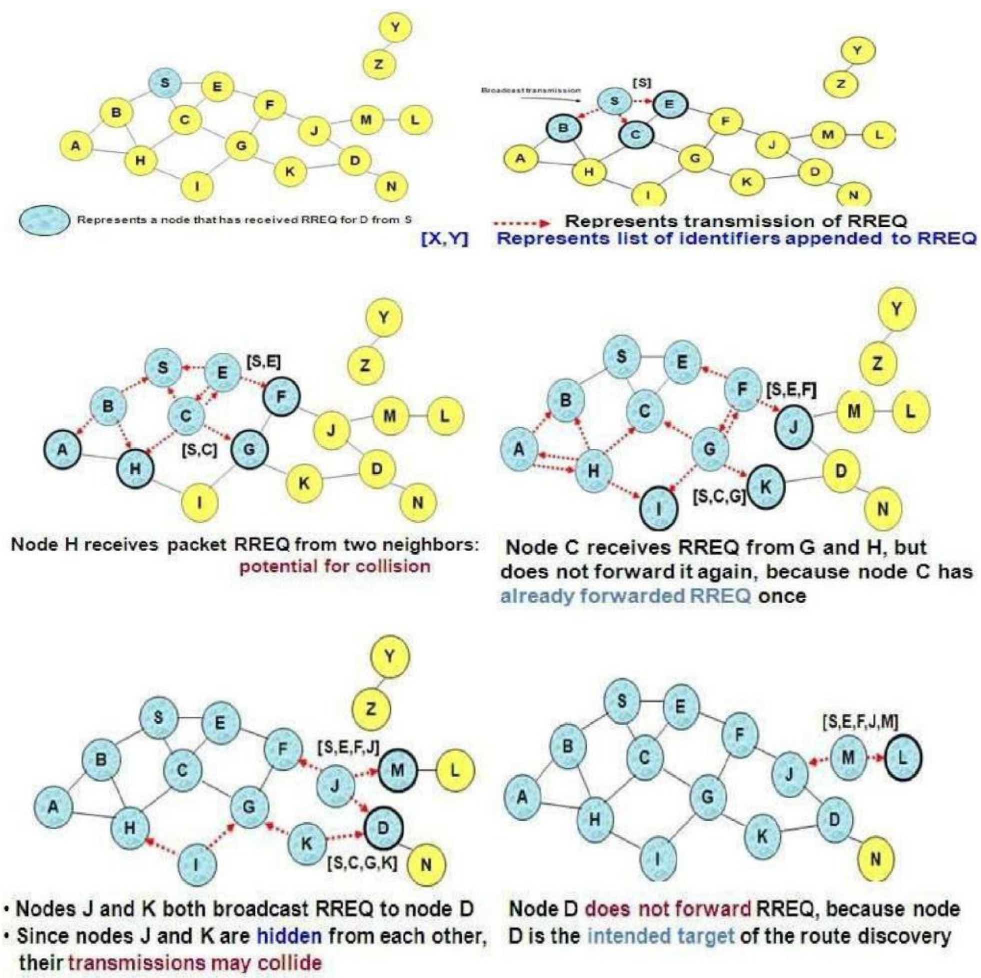
Dynamic Source Routing(DSR)

The Dynamic Source Routing protocol (DSR) is a simple and efficient routing protocol designed specifically for use in multi-hop wireless ad hoc networks of mobile nodes. DSR allows the network to be completely self-organizing and self-configuring, without the need for any existing network infrastructure or administration. The protocol is composed of the two main mechanisms of "Route Discovery" and "Route Maintenance", which work together to allow nodes to discover and maintain routes to arbitrary destinations in the ad hoc network. All aspects of the protocol operate entirely on-demand, allowing the routing packet overhead of DSR to scale automatically to only that needed to react to changes in the routes currently in use.

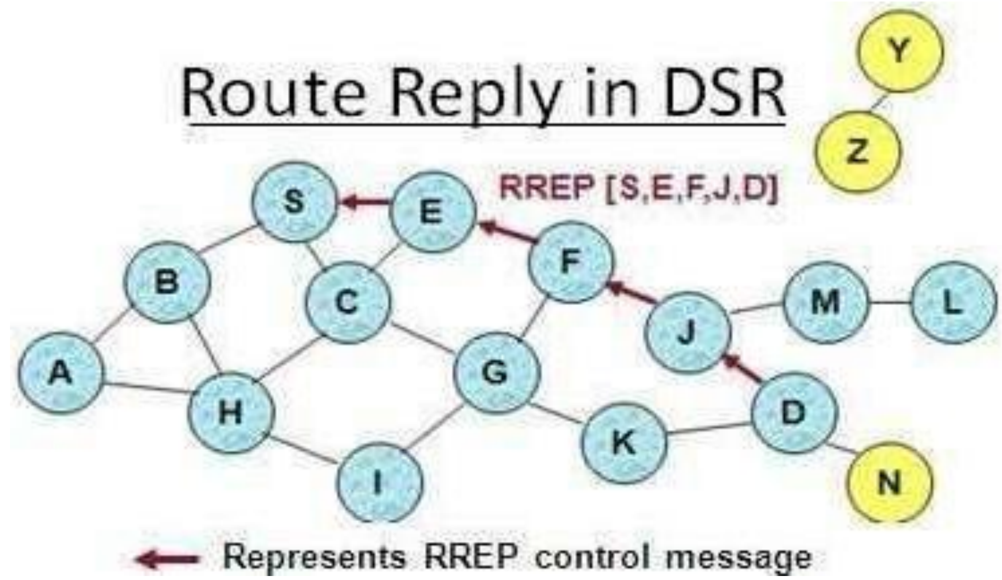
Route discovery. If the source does not have a route to the destination in its route cache, it broadcasts a route request (RREQ) message specifying the destination node for which the route is requested. The RREQ message includes a route record which specifies the sequence of nodes traversed by the message. When an intermediate node receives a RREQ, it checks to see if it is already in the route record. If it is, it drops the message. This is done to prevent routing loops. If the intermediate node had received the RREQ before, then it also drops the message. The intermediate node forwards the RREQ to the next hop according to the route specified in the header. When the destination receives the RREQ, it sends back a route reply message. If the destination has a route to the source in its route cache, then it can send a route response (RREP) message along this route. Otherwise, the RREP message can be sent along the reverse route back to the source. Intermediate nodes may also use their route cache to reply to RREQs. If an intermediate node has a route to the destination in its cache, then it can append the route to the route record in the RREQ, and send an RREP back to the source containing this route. This can help limit flooding of the RREQ. However, if the cached route is out-of-date, it can result in the source receiving stale routes.

Route maintenance. When a node detects a broken link while trying to forward a packet to the next hop, it sends a route error (RERR) message back to the source containing the link in error. When an RERR message is received, all routes containing the link in error are deleted at that node.

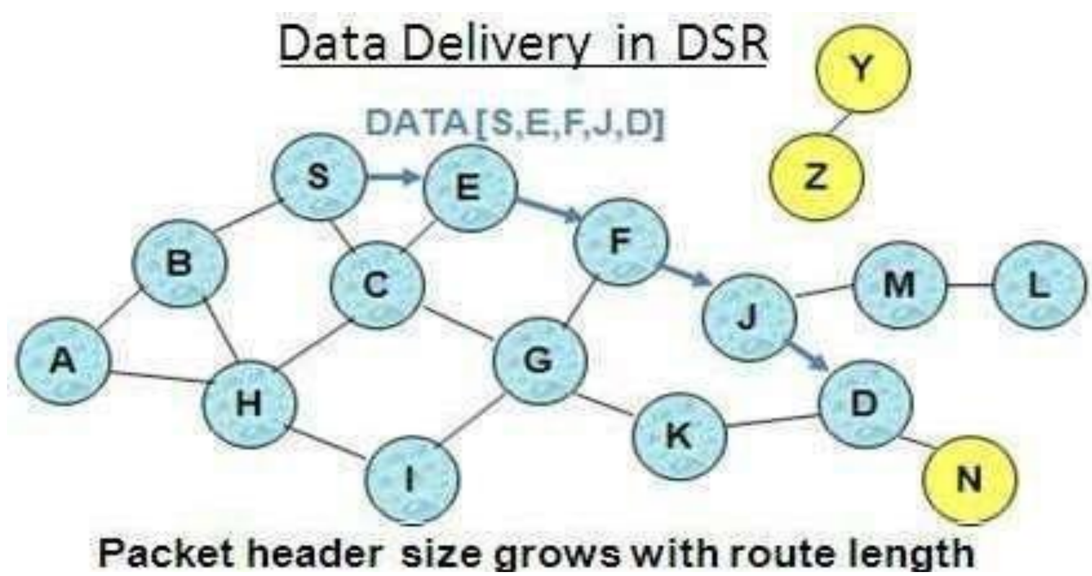
As an example, consider the following MANET, where a node S wants to send a packet to D, but does not know the route to D. So, it initiates a route discovery. Source node S floods Route Request (RREQ). Each node appends its own identifier when forwarding RREQ as shown below.



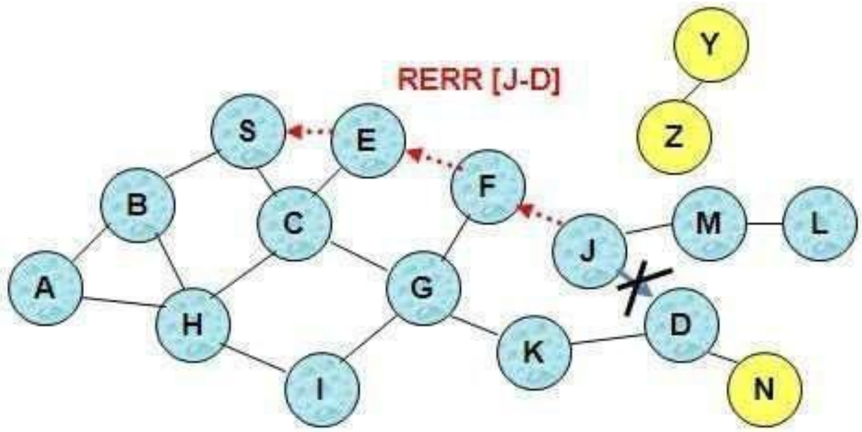
Destination D on receiving the first RREQ, sends a Route Reply (RREP). RREP is sent on a route obtained by reversing the route appended to received RREQ. RREP includes the route from S to D on which RREQ was received by node D.



Route Reply can be sent by reversing the route in Route Request (RREQ) only if links are guaranteed to be bi-directional. If Unidirectional (asymmetric) links are allowed, then RREP may need a route discovery from S to D. Node S on receiving RREP, caches the route included in the RREP. When node S sends a data packet to D, the entire route is included in the packet header {hence the name source routing}. Intermediate nodes use the source route included in a packet to determine to whom a packet should be forwarded.



J sends a route error to S along route J-F-E-S when its attempt to forward the data packet S (with route SEFJD) on J-D fails. Nodes hearing RERR update their route cache to remove link J-D



Advantages of DSR:

- Routes maintained only between nodes who need to communicate-- reduces overhead ofroute maintenance
- Route caching can further reduce route discovery overhead
- A single route discovery may yield many routes to the destination, due to intermediatenodes replying from local caches

Disadvantages of DSR:

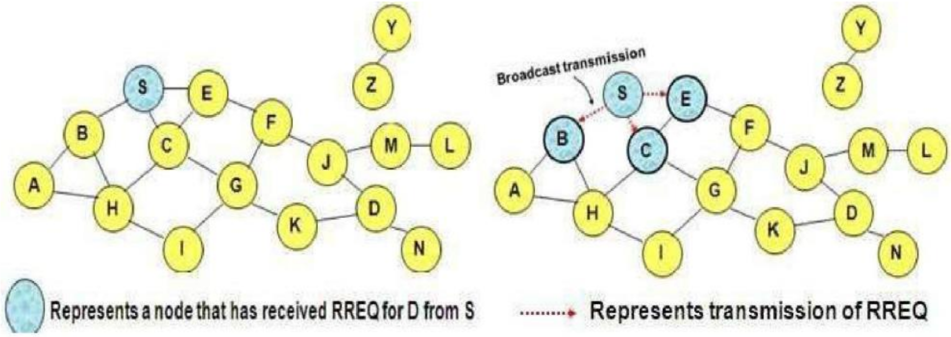
- Packet header size grows with route length due to source routing
- Flood of route requests may potentially reach all nodes in the network
- Care must be taken to avoid collisions between route requests propagated byneighboring nodes -- insertion of random delays before forwarding RREQ
- Increased contention if too many route replies come back due to nodes replying using their local cache-- Route Reply Storm problem. Reply storm may be eased by preventing a node from sending RREP if it hears another RREP with a shorter route
- An intermediate node may send Route Reply using a stale cached route, thus pollutingother caches

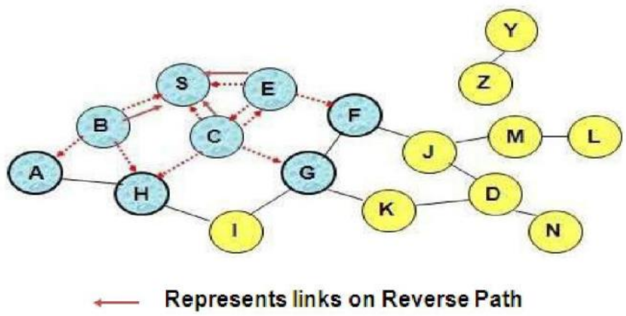
An optimization for DSR can be done called as Route Caching. Each node caches a new route it learns by any means. In the above example, When node S finds route [S,E,F,J,D] to node D, node S also learns route [S,E,F] to node F. When node K receives Route Request [S,C,G] destined for node, node K learns route [K,G,C,S] to node S. When node F forwards Route Reply RREP [S,E,F,J,D], node F learns route [F,J,D] to node D. When node E forwards Data [S,E,F,J,D] it learns route [E,F,J,D] to node D. A node may also learn a route when it overhears Data packets. Usage of Route cache can speed up route discovery and can also reduce propagation of route requests. The disadvantages are, stale caches can adversely affect performance. With passage of time and host mobility, cached routes may become invalid.

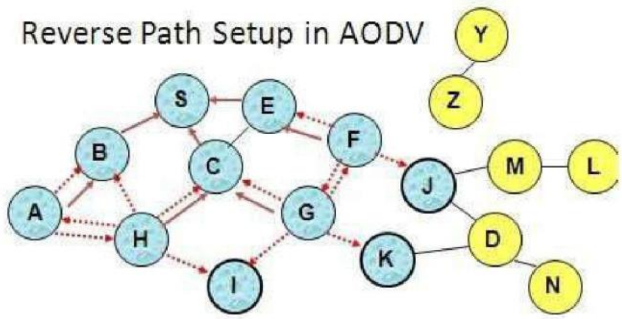
Ad Hoc On-Demand Distance Vector Routing (AODV)

AODV is another reactive protocol as it reacts to changes and maintains only the active routes in the caches or tables for a pre-specified expiration time. Distance vector means a set of distant nodes, which defines the path to destination. AODV can be considered as a descendant of DSR and DSDV algorithms. It uses the same route discovery mechanism used by DSR. DSR includes source routes in packet headers and resulting large headers can sometimes degrade performance, particularly when data contents of a packet are small. AODV attempts to improve on DSR by maintaining routing tables at the nodes, so that data packets do not have to contain routes. AODV retains the desirable feature of DSR that routes are maintained only between nodes which need to communicate. However, as opposed to DSR, which uses source routing, AODV uses hop-by-hop routing by maintaining routing table entries at intermediate nodes.

Route Discovery. The route discovery process is initiated when a source needs a route to a destination and it does not have a route in its routing table. To initiate route discovery, the source floods the network with a RREQ packet specifying the destination for which the route is requested. When a node receives an RREQ packet, it checks to see whether it is the destination or whether it has a route to the destination. If either case is true, the node generates an RREP packet, which is sent back to the source along the reverse path. Each node along the reverse path sets up a forward pointer to the node it received the RREP from. This sets up a forward path from the source to the destination. If the node is not the destination and does not have a route to the destination, it rebroadcasts the RREQ packet. At intermediate nodes duplicate RREQ packets are discarded. When the source node receives the first RREP, it can begin sending data to the destination. To determine the relative degree out-of-datedness of routes, each entry in the node routing table and all RREQ and RREP packets are tagged with a destination sequence number. A



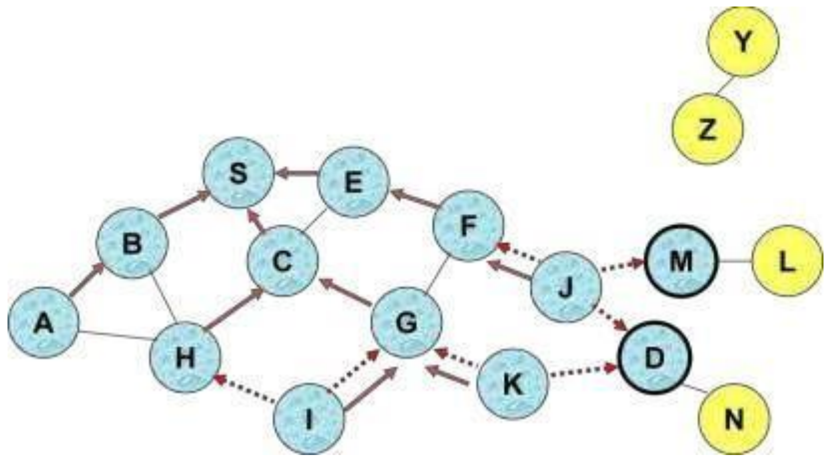


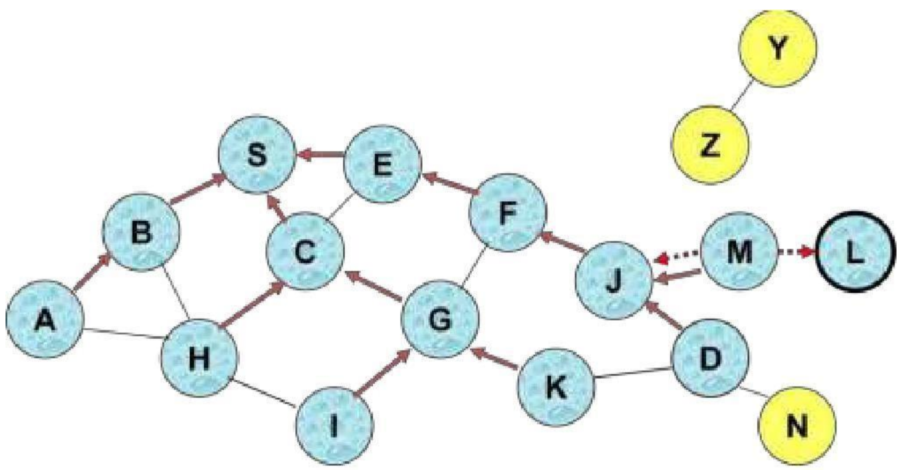


Node C receives RREQ from G and H, but does not forward it again, because node C has already forwarded RREQ once

larger destination sequence number indicates a more current (or more recent) route. Upon receiving an RREQ or RREP packet, a node updates its routing information to set up the reverse or forward path, respectively, only if the route contained in the RREQ or RREP packet is more current than its own route.

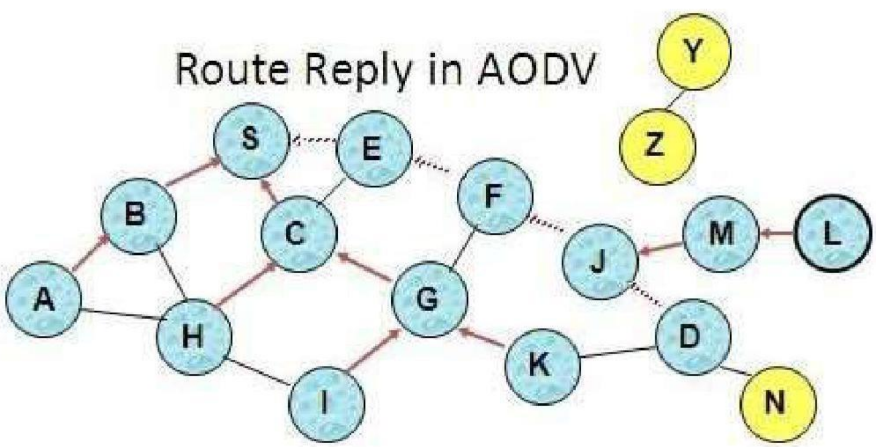
Route Maintenance. When a node detects a broken link while attempting to forward a packet to the next hop, it generates a RERR packet that is sent to all sources using the broken link. The RERR packet erases all routes using the link along the way. If a source receives a RERR packet and a route to the destination is still required, it initiates a new route discovery process. Routes are also deleted from the routing table if they are unused for a certain amount of time.





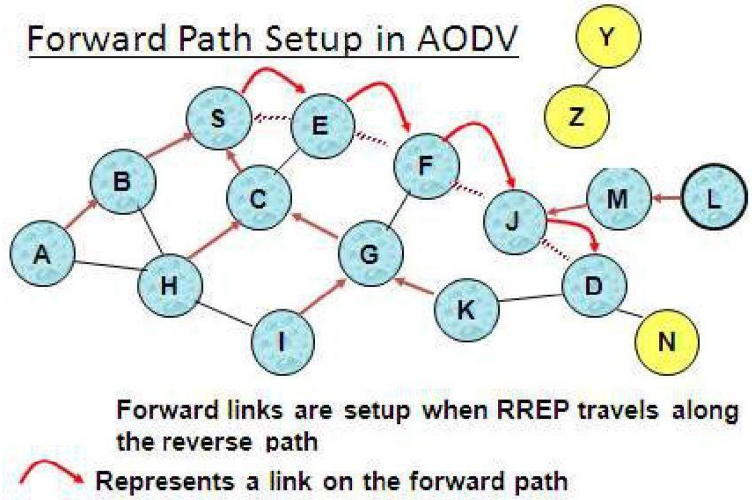
Node D does not forward RREQ, because node D is the intended target of the RREQ

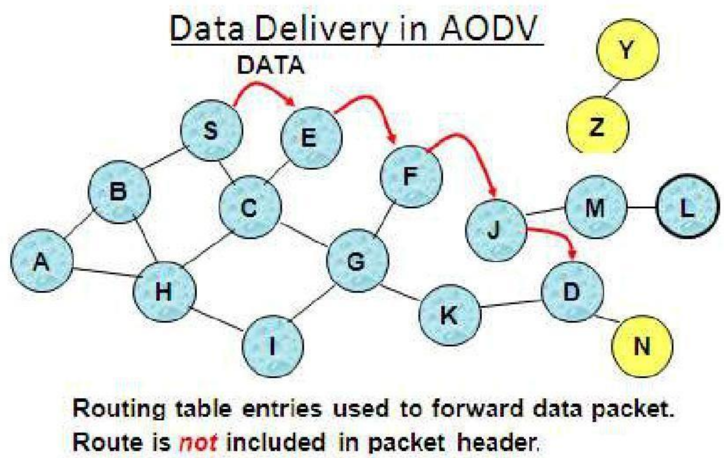
Route Reply in AODV



Represents links on path taken by RREP

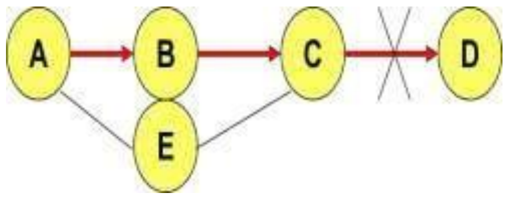
An intermediate node (not the destination) may also send a Route Reply (RREP) provided that it knows a more recent path than the one previously known to sender S. To determine whether the path known to an intermediate node is more recent, destination sequence numbers are used. The likelihood that an intermediate node will send a Route Reply when using AODV is not as high as DSR. A new Route Request by node S for a destination is assigned a higher destination sequence number. An intermediate node which knows a route, but with a smaller sequence number, cannot send Route Reply





When node X is unable to forward packet P (from node S to node D) on link (X,Y), it generates a RERR message Node X increments the destination sequence number for D cached at node X. The incremented sequence number N is included in the RERR. When node S receives the RERR, it initiates a new route discovery for D using destination sequence number at least as large as N. When node D receives the route request with destination sequence number N, node D will set its sequence number to N, unless it is already larger than N.

Sequence numbers are used in AODV to avoid using old/broken routes and to determine which route is newer. Also, it prevents formation of loops.



Assume that A does not know about failure of link C-D because RERR sent by C is lost.

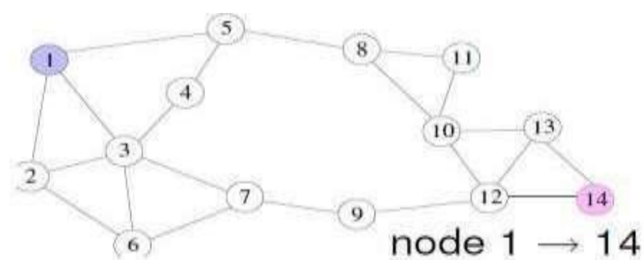
Now C performs a route discovery for D. Node A receives the RREQ (say, via path C-E-A)

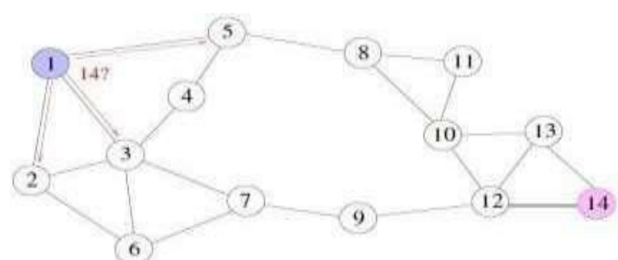
Node A will reply since A knows a route to D via node B resulting in a loop (for instance, C-E-A-B-C)

Neighboring nodes periodically exchange hello message and absence of hello message indicates a link failure. When node X is unable to forward packet P (from node S to node D) on link (X,Y), it generates a **RERR message**. Node X increments the destination sequence number for D cached at node X. The incremented sequence number N is included in the RERR. When node S receives the RERR, it initiates a new route discovery for D using destination sequence number at least as large as N. When node D receives the route request with destination sequence number N, node D will set its sequence number to N, unless it is already larger than N.

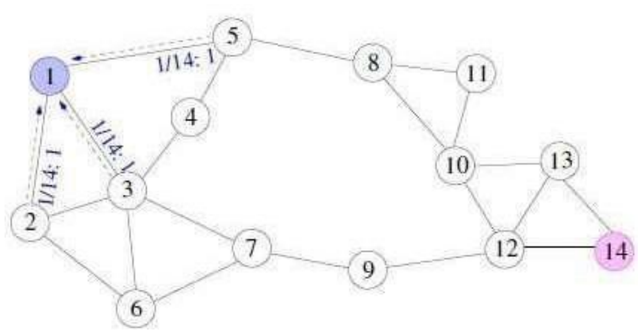
Another example for AODV protocol:

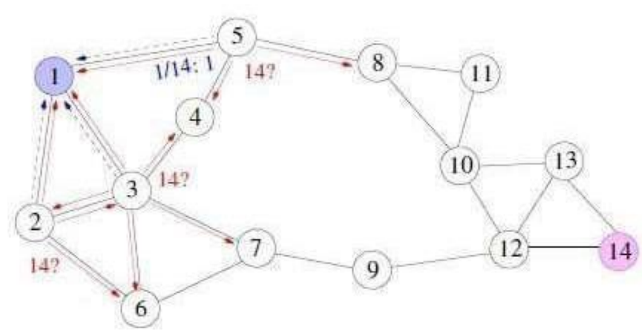
Assume node-1 want to send a msg to node-14 and does not know the route. So, it broadcasts (floods) route request message, shown in red.



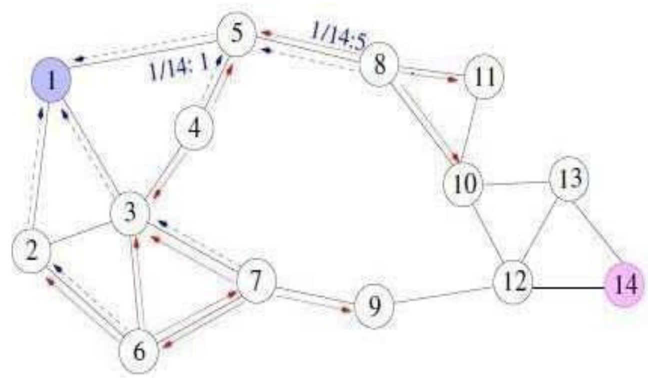


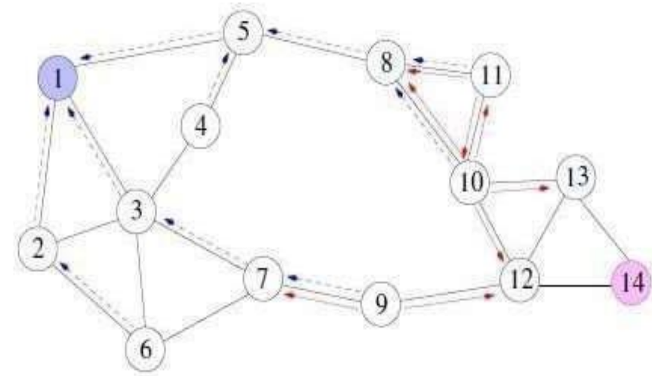
Node from which RREQ was received defines a reverse route to the source. (reverse routing table entries shown in blue).



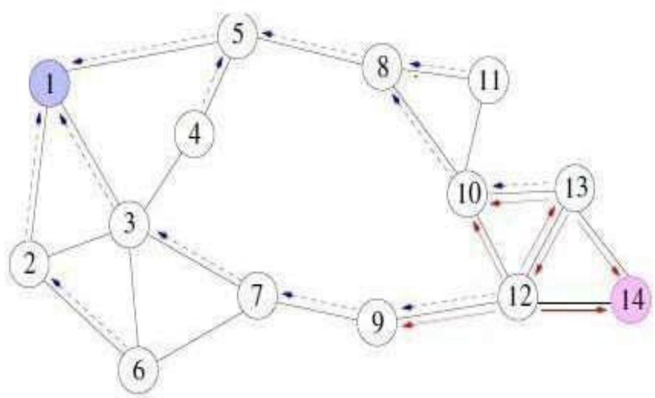


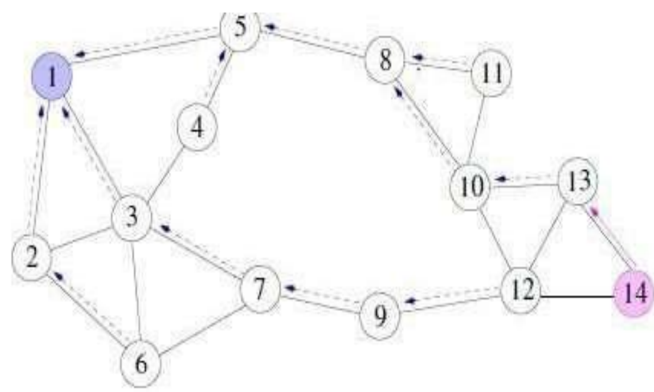
The route request is flooded through the network. Destination managed sequence number, ID prevent looping. Also, flooding is expensive and creates broadcast collision problem.



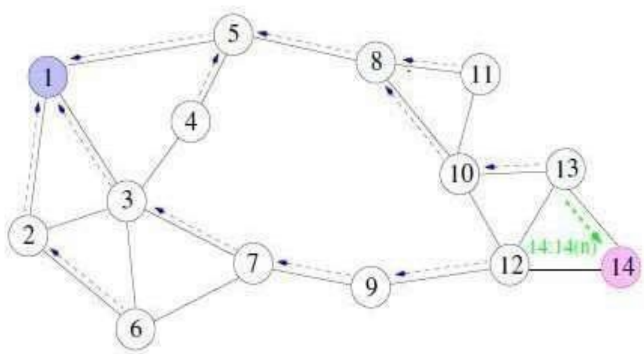


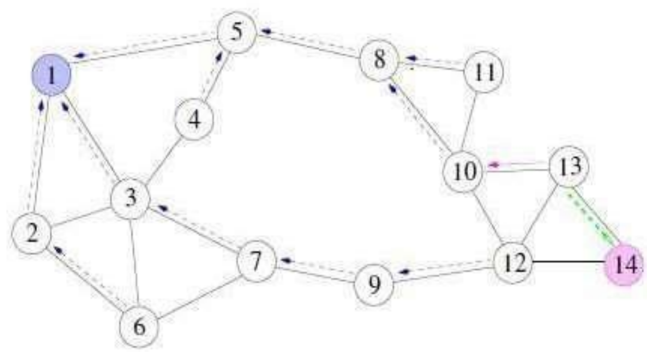
Route request arrives at the destination node-14. Upon receiving, destination sends route reply by setting a sequence number(shown in pink)



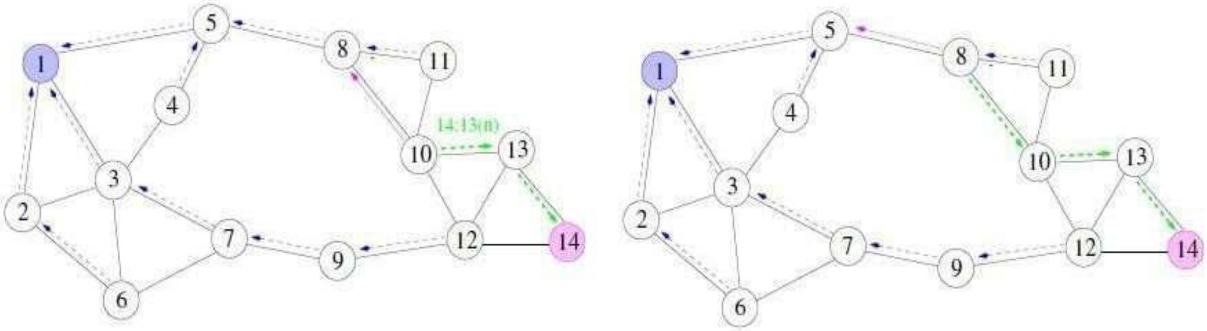


Routing table now contains forward route to the destination. Route reply follows reverse route back to the source.

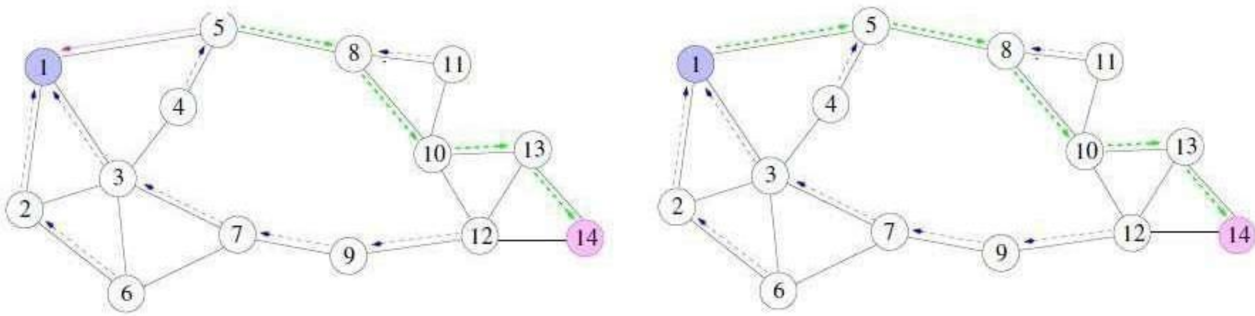




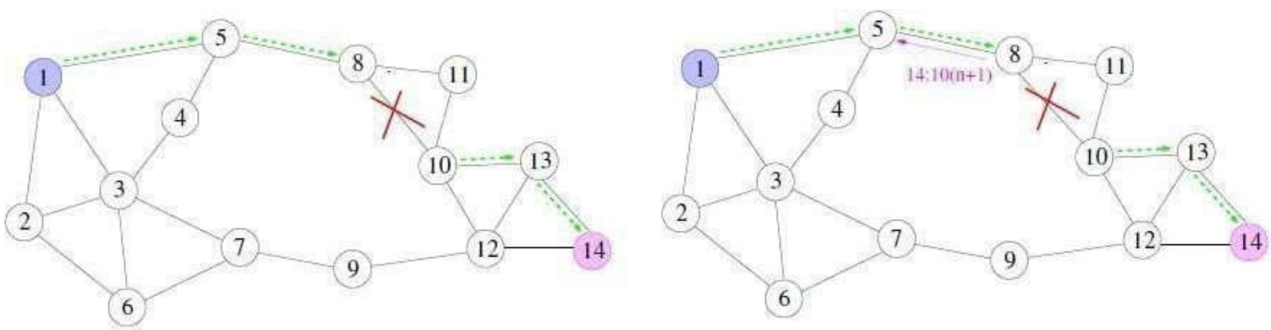
The route reply sets the forward table entries on its way back to the source.



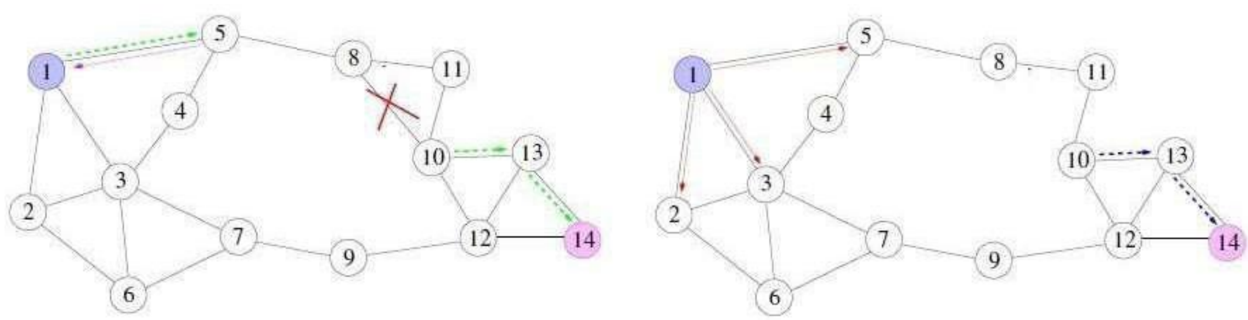
Once the route reply reaches the source, it adopts the destination sequence number. Traffic flowsalong the forward route. Forward route is refreshed and the reverse routes get timedout.



Suppose there has been a failure in one of the links. The node sends a return error message to the source with incrementing the sequence number.



Once the source receives the route error, it re-initiates the route discoveryprocess.



A routing table entry maintaining a reverse path is purged after a timeout interval. Timeout should be long enough to allow RREP to come back. A routing table entry maintaining a forward path is purged if not used for a active_route_timeout interval. If no data is being sent using a particular routing table entry, that entry will be deleted from the routing table (even if the route may actually still be valid).

Security in MANET‘s

Securing wireless ad-hoc networks is a highly challenging issue. Understanding possible form of attacks is always the first step towards developing good security solutions. Security of communication in MANET is important for secure transmission of information. Absence of any central co-ordination mechanism and shared wireless medium makes MANET more vulnerable to digital/cyber attacks than wired network there are a number of attacks that affect MANET.

These attacks can be classified into two types:

1. External Attack: External attacks are carried out by nodes that do not belong to the network. It causes congestion sends false routing information or causes unavailability of services.

2. Internal Attack: Internal attacks are from compromised nodes that are part of the network. In an internal attack the malicious node from the network gains unauthorized access and impersonates as a genuine node. It can analyze traffic between other nodes and may participate in other network activities.

- **Denial of Service attack**: This attack aims to attack the availability of a node or the entire network. If the attack is successful the services will not be available. The attacker generally uses radio signal jamming and the battery exhaustion method.
- **Impersonation**: If the authentication mechanism is not properly implemented a malicious node can act as a genuine node and monitor the network traffic. It can also send fake routing packets, and gain access to some confidential information.
- **Eavesdropping:** This is a passive attack. The node simply observes the confidential information. This information can be later used by the malicious node. The secret information like location, public key, private key, password etc. can be fetched by eavesdropper.
- **Routing Attacks:** The malicious node makes routing services a target because its an important service in MANETs. There are two flavors to this routing attack. One is attack on routing protocol and another is attack on packet forwarding or delivery mechanism. The first is aimed at blocking the propagation of routing information to a node. The latter is aimed at disturbing the packet delivery against a predefined path.
- **Black hole Attack:**: In this attack, an attacker advertises a zero metric for all destinations causing all nodes around it to route packets towards it.[9] A malicious node sends fake routing information, claiming that it has an optimum route and causes other good nodes to route data packets through the malicious one. A malicious node drops all packets that it receives instead of normally forwarding those packets. An attacker listen the requests in a flooding based protocol.
- **Wormhole Attack:** In a wormhole attack, an attacker receives packets at one point in

the network from that point. Routing can be disrupted when routing control message are tunnelled. This tunnel between two colluding attacks is known as a wormhole.

- **Replay Attack:** An attacker that performs a replay attack are retransmitted the valid data repeatedly to inject the network routing traffic that has been captured previously. This attack usually targets the freshness of routes, but can also be used to undermine poorly designed security solutions.
- **Jamming:** In jamming, attacker initially keep monitoring wireless medium in order to determine frequency at which destination node is receiving signal from sender. It then transmit signal on that frequency so that error free receptor is hindered.
- **Man- in- the- middle attack:** An attacker sites between the sender and receiver and sniffs any information being sent between two nodes. In some cases, attacker may impersonate the sender to communicate with receiver or impersonate the receiver to reply to the sender.
- **Gray-hole attack**: This attack is also known as routing misbehavior attack which leads to dropping of messages. Gray-hole attack has two phases. In the first phase the node advertise itself as having a valid route to destination while in second phase, nodes drops intercepted packets with a certain probability.

The Wireless Application Protocol (WAP) is an open, global specification that empowers mobile users with wireless devices to easily access and interact with information and services instantly.

WAP is a global standard and is not controlled by any single company. Ericsson, Nokia, Motorola, and Unwired Planet founded the **WAP Forum** in the summer of 1997 with the initial purpose of defining an industry-wide specification for developing applications over wireless communications networks. The WAP specifications define a set of protocols in application, session, transaction, security, and transport layers, which enable operators, manufacturers, and applications providers to meet the challenges in advanced wireless service differentiation and fast/flexible service creation.

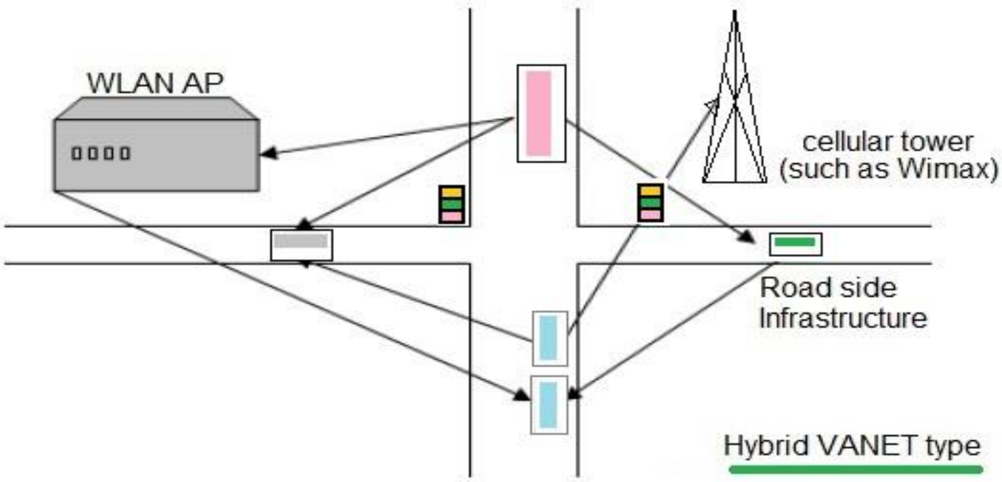
All solutions must be:

- **interoperable,** i.e., allowing terminals and software from different vendors to communicate with networks from different providers
- **scaleable,** i.e., protocols and services should scale with customer needs and number of customers
- **efficient,** i.e., provision of QoS suited to the characteristics of the wireless and mobile networks
- **reliable,** i.e., provision of a consistent and predictable platform for deploying services; and
- **secure,** i.e., preservation of the integrity of user data, protection of devices and services from security problems.

VANET

It is the short form of Vehicular Adhoc Network. It is subgroup of network of MANET type.

The routing protocols of MANET are not feasible to be used in the VANET network. If they are used then also they will not be able to deliver required throughput as it has fast changing adhoc network.



In VANET, the communication nodes are moving on pre-defined roads as finalized initially.

The VANET architecture consists of three type of categories as mentioned below:
• cellular and WLAN network
• Pure Ad hoc (network between vehicles and fixed gateways)
• hybrid(combination of both infrastructure and adhoc networks), as shown in figure.

In the first type, fixed gateways and WiMaX/WiFi APs are used at traffic junctions to connect with the internet, to obtain traffic information and used for routing.

The VANET nodes are not subject to storage and power limitation.

Following table mentions difference between MANET and VANET types.

Characteristics	**MANET**	**VANET**
Node Mobility	Low	High
Node Speed	Lower (~ 6 Km/h)	Medium to high (~ 20 to 100 Km/h)
Mobility Model	Random	Regular
Node Density	Low	High
Topology Change	Slow	Fast
Radio propagation model	Close to Ground, LoS is not available for all cases	Close to Ground, LoS is not available for all cases
Power consumption and network lifetime	Energy efficiency protocols	Not needed
Computational Power	Limited	High
Localization	GPS	GPS, AGPS, DGPS
Cost	Inexpensive	Costly

Bandwidth	Hundred Kbps	Thousand Kbps
Range	Upto 100 meters	Upto 600 meters