# SCENARIO-DRIVEN DESIGN CONSIDERATIONS FOR MANET PROTOCOLS

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**Abstract:** The Mobile Ad-hoc Network (MANET) research aims at developing Internet routing protocols for networks of mobile nodes with limited resources. It has focused on discovering suitable basic routing algorithms in isolated, homogeneous MANET environments. Little emphasis has so far been given to practical usage scenarios and their implications to the MANET solutions.

Based on simple observations of some usage scenarios we claim that node and service attributes, access out of a MANET, and adaptability to different usage environments in practice are features important enough to be considered at the protocol level. In the ongoing Mobile Ad-hoc Routing Testbed (MART) project, a practical multi-protocol MANET environment is being implemented with support for some important service attributes, such as the access out of MANET.

**Keywords:** Adaptability, adhoc networks, attributes, IP, routing, usage scenarios

## 1 INTRODUCTION

In search for new wireless mobile data networking solutions, some recent networking research has been focused on the Mobile Ad-hoc Networks, or MANETs (Figure 1). As opposed to hierarchical networks with fixed basestations, these networks are composed



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of equal nodes which communicate among themselves over wireless links without any central control.

The nodes in MANET route each other's data so that the node is both a host and a router. The equality of nodes, the spontaneous and dynamic topology of the network, and the use of wireless link-level media give rise to a special kind of network characteristics, informally defined in the IETF MANET Working Group drafts [4, 18]. Practical use cases envisioned [9] for MANET include

- military tactical networks, where the infrastructure is rapidly deployed to difficult environments,
- use by mobile services such as rescue, security, or law enforcement,
- as provisionary networks in conferences, exhibitions, or events where fixed infrastructure is not at hand, or
- for networking among embedded control devices.

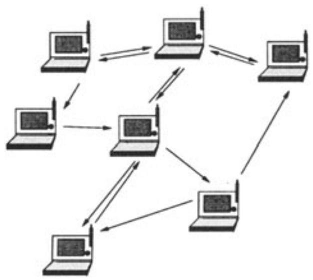

Figure 1. A mobile ad-hoc network.

Characteristic to the current definition of MANET is that mobile, wireless hosts form an arbitrarily moving mesh of equal nodes. These communicate among themselves over uni- or bidirectional, possibly multihop routes with no specific patterns or distribution of communication activity.

## 2 A VIEW OF MANET WORK

The recent MANET work has been focused on creating algorithms to perform the basic routing within a MANET, intended to be used with the current IPv4 networking protocols. Due to the special network characteristics, traditional routing protocols used in fixed networks [11, 13, 16] are not adequate for MANETs [8]. Several routing protocols have been suggested, most of them to implement unicast routing in the ad-hoc network [2, 5, 10, 14, 19], and some also for multicast routing [19].

A very simple protocol, flooding, can be used to illustrate behavior present in a MANET. In flooding, a node advertises its presence by periodically broadcasting a hello message. This contains the address of the node, a metric, and a sequence number. When another node receives the message and has not yet seen it, the receiving node updates its route to the destination, and rebroadcasts the message. Otherwise the message is ignored. The metric increases as the message gets re-broadcast. The sequence number is unique to a hello message and it is used to distinguish if a copy of the message has already been seen by the receiver.

Flooding is an example of a *proactive* protocol that establishes routes before they are needed. This generates much control traffic but enables fast reaction to routing needs. There are also *reactive* protocols which create routes on demand with less routing traffic, especially during low communication activity. Many protocols belong to both categories.

Some of the MANET algorithms have been evaluated by means of simulation [4], [3, 17]. In most simulations, the algorithms have been compared against each other, and against some other routing algorithms in fairly homogeneous scenarios. In these scenarios the nodes often communicate and move with random patterns in a uniform environment.

## 3 A SCENARIO-DRIVEN APPROACH—A CRITIQUE

The models/scenarios used in above mentioned algorithm analysis papers have done many simplifying assumptions. These scenarios are good for modeling behavior at a general level but not so precise for capturing all the diversity in practical systems.

### *3.1 Plausible Scenarios*

The diversity in practical scenarios can be illustrated with simple informal examples.

**Home Network.** In a home network scenario, a MANET might be composed of several small nodes rather than many desktop computers. The small nodes can be wearable devices or devices embedded to consumer electronics. These kinds of nodes have only limited configurability and anemic resources, such as power, memory, or speed.

The size and geographical span of the network, and the node mobility is small. The network is most likely a single stub subnet with no transit traffic through it. Access out of the MANET occurs through a single slow access point, which can be non-continuously available. The users are non-motivated non-experts so that the needed properties include easy configuration, reasonable response times, and robustness rather than capacity, or mobility.

Attributes needed in the above example are those used for auto-configuring access out of the MANET. These are elements of the basic network interface, i.e. host IP address visible to the outside, hostname, domainname, name server, and the default route. These can be taken care of by using the DHCP [6], NAT [7], and DNS [15] services, but efficiency considerations suggest that some of these attributes should be used within the MANET protocols.

**Campus Network.** In the campus, we have a rich mix of devices from small to large, fixed to mobile, many access points to many subnets with continuous broadband access, and users with varying skills and patience. Network size and span is large, while the node mobility is typically small. In this scenario we need capacity, scalability, and flexible, responsive adaptation to a rich service environment, but not very fast mobility.

Interesting attributes here would include those of the previous scenario and those that tell more about the alternative access points. Interesting for the gateway selection would be to know if the access point is a fixed node with good resources or an anemic one, and, perhaps, what is the capacity of the offered access.

**Department Store.** In a department store scenario, we can envision a moving crowd with lots of anemic nodes while the environment has a sizable fixed infrastructure. This scenario calls for scalability, and is in an environment with frequent, although not necessarily very fast mobility. Connections out of MANET occur through many nodes in many subnets.

Important for this usage scenario is that the network does not completely break down due to poor scalability. Thus, network data traffic activity, network scale, and node mobility are attributes that should be carefully used to find the most enduring protocol mode. In this scenario, it is likely that the current protocol must be chosen based on a combination of these attributes. So, this scenario is a candidate which could benefit from multiprotocol support that adapts to network conditions.

**Freeway.** On the freeway, we have a few fast moving nodes with more predictable mobility patterns than in the previous scenarios. Nodes are small, similar, and use must be easy, which implies that self-configuration is desirable. Fast mobility is now particularly important.

Attributes that support fast mobility are needed, and possibly even a special new protocol mode that is the most resilient in fast mobility conditions. Simulation work reported by others [17] suggest that pure flooding could be such.

### 3.2 A Synthesis

From the usage scenarios we can make observations that can affect MANET solutions. These observations have contributed to the chosen implementation approach.

**There is no single MANET solution**. It is hard to convince everybody that one algorithm would be optimal for all possible scenarios of the MANET world. For example, a strongly proactive protocol gives a faster respose than a very reactive protocol. On the other hand, a reactive protocol consumes less bandwidth than a proactive one in situations where the average communication among nodes is small. Therefore, it should be possible to use several algorithms in a MANET.

**A plausible MANET solution needs self learning.** With respect to the above mentioned scenarios, the same mobile node can be used in various places. There are parameters in individual algorithms that one might want to adjust. Given that one algorithm hardly fulfills all needs, the ability to automatically switch between algorithms becomes important. There are also parameters external to the actual algorithms that should be adjustable, such as user-policy based, or local ones. An example of such parameters might be the power saving mode a node is in.

Moreover, support for non-homogeneous software platforms, and software implementations requires a possibility to negotiate algorithms and their parameters, for example in situations where different versions of a protocol exists. Therefore, the nodes must *adapt*, e.g., tune themselves to use efficient settings by using environment and history. There could be a monitoring function that adjusts the parameters of the MANET protocols and switches between algorithms according to some protocol mode transition rules.

**Nodes have several attributes.** Given the above scenarios, one can see that there are nodes which have very different time-invariant features. Some can be used for very extensive computing needs while others can be quite small-scale being part of embedded or wearable devices.

Physical properties of the nodes are different. The available power (battery), and processing capacity may vary. Transmitting data is one of the most power-consuming functions, so that transmission should be avoided in anemic nodes whereas fixed power nodes may waste transmission energy more freely. The mobility pattern of different nodes vary greatly from fixed location nodes to highmobility ones. Therefore, the nature and properties of the nodes themselves influence the routing decisions.

Attributes such as those describing node characteristics, processing capacity, ownership and security relationships, or network characteristics such as radio capacity on alternative technologies all influence routing. Thus, the routing decision shall be based on a set of attributes and on their values. Additionally, nodes shall be capable of informing other nodes on their available services, and service needs.

**Interaction with the outside world is fundamental in practice.** In most practical MANET scenarios, access to public Internet and its services is vital. Therefore, influence of this access to MANET routing should be taken into consideration in the protocols.

We might want to select the closest access point to the fixed network or that with the greatest capacity. One may also want to optimize the communication with respect to cost, power consumption, or some quality of service parameters. These are usually different between fixed network and the wireless MANET. To select and use the access in an efficient manner requires adaptation decisions and information to make them on.

**MANET is not optimal for all uses.** There are several mobility management protocols, like the MobileIP, VPN, or those in the cellular networks, which provide different levels of mobility for the user. For example, when combining MobileIP and MANET, the selection of the access point influences also mobility management in MobileIP. The different levels of mobility management should cooperate with each other by exchanging parameters and needs.

## 4 MART-PROJECT

The Mobile Ad-hoc Routing Testbed (MART) project is developing a MANET test implementation for a selected set of users in the context of the on-going wireless infrastructure buildup at the Helsinki University of Technology, Finland. We are currently implementing a multi-protocol MANET router prototype for Linux [20]. It supports multiple network interfaces per node, and multiple subnets with simultaneous use of different link-level technologies. Currently, we use flooding, a simple proactive protocol, in initial test setups with preliminary support for multi-protocol routing in a MANET, and attribute advertisement, currently concentrating on attributes useful for providing access out of MANET.

The support for multiple protocols currently means that the router can select between alternative protocols according to the protocol type identifier in a received protocol message. The identifier has been chosen in this work as the first byte for all messages in all the protocols under implementation. The protocols do not currently cooperate, but they rather coexist in the same router. Each node knows a current protocol which is used for the routing needs of the node itself. The multi-protocol support then allows for the node to support other protocols so that the node can handle routing messages of these protocols independent of the current protocol.

As an example of attribute extensions on the routing protocol level, the fixed network access functionality has been implemented to the prototype. The attributes of access out of MANET are advertised by the gateways as a part of the MANET protocol. The gateway advertises its access attributes by periodically flooding an advertisement message to the MANET (Figure 2).

The access advertisement for access point `dest` contains the network `dnw`, and the netmask `dnm` of the subnet where the access node is with address `dgw` in the fixed network. A requirement here to use the access point is that the node has an address in that subnet so that the gateway can proxy arp that visible address. The `type` distinguishes this message, the `V` bit tells if the `dest` is a node address that is part of the gateway's subnet, meaning that it is visible in an access gateway, and the `hopcnt` is the route metric.

```
typedef struct {
    uint8 type;
    struct {
        short V : 1;
        int reserved : 15;
    } floodingbits;
    uint8 hopcnt;
    uint32 dest;
    uint32 dsn;
    uint32 dgw;
    uint32 dnw;
    uint32 dnm;
} flooding_msg_t;
```

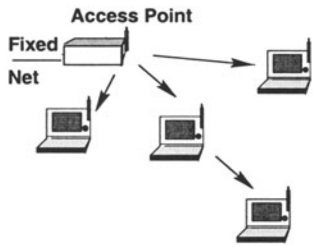


Figure 2. A gateway advertises access.

When a node discovers a suitable gateway, it configures the default route as the next hop of the outbound route to that gateway. The default policy for using the access information currently is that the node selects the access gateway with the shortest metric. This decision could later have more intelligence and be based on a more descriptive access point advertisements.

**Practical considerations.** The router has been implemented so that it conforms to the Requirements for IP Version 4 Routers [1], except in that received IP data packets can be forwarded to the same network interface from which they came. This is needed for the wireless interfaces to enable repeater functionality in the mobile nodes. The feature is implemented with a simple patch for selected Linux kernels.

Broadcasts for the beaconing protocols are currently sent to the directed (subnet) broadcast address, and not to the limited (all bits 1) broadcast address, like was done in [12], so that we can easily have multiple interfaces in a node, and multiple isolated MANETs in the same space.

## 5 CONCLUSIONS

In this paper, we have collected a set of practical criteria that a MANET protocol should fulfill to be truly scalable. Our examination of usage scenarios suggests that there are attributes important enough to be considered on the MANET protocol level. Our specific approach is to add this support when designing a practically functional MANET implementation. As an example, access to the outside world, a key feature often ignored with MANET designs, is suitable to be implemented using attribute support.

To implement attribute support suggested in this paper, certain extensions to the MANET protocols should be considered. Obtaining the right kind of flexibility means that multiple protocol types, and type extensions should be supported in a consistent way over all protocols, so that the extensions are only loosely coupled with the basic protocols. This could mean that extensions for advertising certain attributes could be optional, for example.

In the future, the ongoing effort will use the attributes by adding adaptability into the MANET routing. The adaptability involves tuning individual protocols as well as switching between multiple protocols, which is the reason to build support for multiple protocols. This, in turn, will require some studying of possibilities for cooperation between different protocols, and between the routing and applications.

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