

An introduction to Mobile Wireless Mesh Networks

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# Introduction

A mobile wireless mesh-network or MWMN, is a network consisting of devices that communicate wirelessly with peer-to-peer connections; therefore, they are considered decentralized networks and have use cases in decentralizing communication, extending network coverage area, avoiding triangulation methods for tracking network traffic, exploring uncharted territories, search and rescue missions, enabling internet access in areas with limited infrastructure or emergency situations, and much more.

This introductory article aims to cover the fundamentals for understanding how MWMNs operate and presents some of the technical details of such networks, in hopes of giving the reader a better understanding of the technology.

There is a dedicated chapter, pros and cons, for detailing benefits and drawbacks of MWNM systems. Additionally, the routing protocols chapter was included with the purpose of taking a closer look at the innerworkings of MWNM technology.

The current and potential future developments chapter is intended for discussing the current state and the potential future of this technology. This chapter is crucial for offering a contextual understanding of MWMNs today and the potential future. The main topics in this chapter are advancements, obsolescence, and growth of MWMN systems.

# Pros and cons

Like every other technology, mobile wireless mesh technology has both advantages and disadvantages. Deciding if MWMN is the best approach for a given task requires an adequate grasp of the technology’s strengths and limits. This chapter helps the reader understand the shortcomings and advantages that MWMN has over other alternatives.

## Pros

Among the most significant factors for relying on MWMN, resilience is paramount. By design, MWMNs operate in a manner that obviates the need for reliance on every individual node within the network for data transmission. This means that even if some nodes are failing, whether due to downtime or technical failure, data can still be transmitted through the nodes that are still functional. This can be attributed to the flexible nature of MWMNs, where it is possible to implement a system to regularly update and keep track of possible routes to the destination node. Additionally, the mobility of each node provides another safeguard against disconnects between the nodes. By repositioning some of the nodes after losing a node, it is possible to recreate the stable information flow within the network. When it comes to resilience, MWMNs undoubtedly exhibit a robust stronghold.

Mobility in MWMNs allows for increased flexibility and range coverage. It makes MWMNs suitable for remote operations in uncharted territories. One example is the network system implemented for the mars rover missions where a rover on mars sends data to one of the Mars orbiter satellites for it to then be forwarded to NASA’s Deep Space Network facilities on Earth (NASA, 2023). The mars rovers can roam freely while the relay satellites that orbit mars take turns in receiving data from the rovers and transmit the data back to Earth. Accomplishing the same task with a direct connection from the rovers to Earth has its own drawbacks, one of which is the rovers not being able to transmit data to Earth, when the side of Mars the rover is on is facing opposite the direction of Earth.

## Cons

Like every other network technology, MWMNs have their caveats. Such systems are usually challenging to scale because adding more nodes creates overhead and increases complexity in managing or maintaining the network which could impact network performance.

Environmental interference can diminish or nullify the signal strength between the nodes. Environmental factors such as physical structures nearby and signal interference, for example by other radio frequencies, can increase error rates or disrupt communication within the network altogether.

When it comes to power consumption nodes within a MWMN typically run on battery power, which is why power management is crucial. High power consumption by the nodes could lead to frequent battery replacements which can reduce the overall reliability of the network.

If speed is of upmost importance, MWMNs are generally not regarded as high-speed connection networks. The multi-hop nature of such networks introduces additional latency compared to direct point-to-point connections. Moreover, wireless communication technologies of today, like Wi-Fi or Bluetooth, have much lower data transfer rates compared to wired connections. It is also important to note that the distance between the nodes plays a major role in determining data transfer speed. Longer distances between nodes results in lower transfer rates and shorter distances maximize transfer rates.

Another challenge for implementing a MWMN is ensuring the security and privacy of data being transmitted. If one node falls victim to a cyber-attack, it could lead to the whole system being compromised. The hijacked node could be used as a gateway into the network for further intrusion to enable unauthorized access, data leaks, or spreading malware.

# Routing protocols.

There are multitudes of protocols that can be used in a mobile wireless mesh network. This chapter will only look at a few of the most notable protocols.

Protocols used in *ad hoc networks*, networks that are created on-the-fly or temporarily without relying on a pre-existing network, can be classified into three main categories: Table-driven (proactive), On-demand (reactive) and Hybrid protocols (Wheeb & Taher, 2021). Table-driven routing is built on the concept of nodes maintaining a fresh table of destinations alongside routing information to every other node and these are updated periodically (Chougule, Sanadi, & Kamble). Reactive protocols on the other hand seek to set up routes on-demand. In other words, if a node tries to communicate with a node which it has no route to, the routing protocol will try to establish such a route (Andreas, 2004). Hybrid protocols try to utilize the best of both worlds by separating the network into zones, and each zone can connect to other zones using border nodes of a zone (2.9.1.3 Hybrid Routing, 2016). Hybrid protocols use table-driven (proactive) routing when establishing a line between nodes in the same zone and switch to reactive routing when establishing connections to different zones.

While covering the pros and cons of the three types of routing protocols is beyond the scope of this article, understanding the advantages and disadvantages they offer remains vital.

|  |  |  |  |
| --- | --- | --- | --- |
| Type of routing protocol | Advantage | | Disadvantage |
| Table-driven (proactive) | | Lower latency | High overhead (mainting full routing tables) |
| Suitable for both hierarchical and flat network organization | High resource consumption (routing table storage) |
| Up-to-date routing information | Might utilize outdated information in dynamic topologies |
| Quick establishment of routes | Large zones require more resources |
| On-demand (reactive) | | Lower overhead | High latency on first route discovery |
| Efficient resource utilization | Route discovery overhead |
| Well-suited for dynamic topologies | Not suited for real-time applications |
| Free of loops |
| Hybrid | | Balance between speed and flexibility (both static and dynamic topologies) | More complex to implement |
| Reduced overhead | Slow convergence |
| Scalable | Routing latencies |
|  | More resource usage for larger zones |

(Gill & Devi, 2019)

This chapter explores two pivotal protocols: DSDV, because it was one of the earliest routing protocols used in Mobile Ad Hoc Networks, and B.A.T.M.A.N because of its adaptability to changes in the network and its efficiency.

## DSDV (Destination-Sequenced Distance-Vector Routing)

Starting with DSDV (Destination-Sequenced Distance-Vector Routing), one of the most well-known proactive table-driven routing protocols, it makes use of the Bellman-Ford algorithm with certain improvements to find the shortest path between the nodes. One of the key features of this algorithm is solving the routing loop problem, a problem that arises when packets circulate from node to node indefinitely.

A picture containing line, diagram, circle, plot

Description automatically generatedFigure 1 shows a network that consists of three nodes, A, B and C. Ideally A would transmit data to C through B because the total weight of the path ABC (4) is shorter than the direct path AC (11). Now assume that path BC suddenly gets disconnected and node A is attempting to send data to C through B (path ABC). Node B is aware of the disconnect on path BC and attempts to connect to C through A (path BAC), in other words, B sends the data it got from A back to A. Node A will then check its routing table and see that there is a better connection to C through B, because B has not informed A about the disconnect of the path BC. Ultimately, this results in the routing loop problem.

Figure 1: Illustration of the routing loop problem.

(Routing loop, 2023)

DSDV solves the routing loop problem by keeping track of the sequence number for each destination node. When a node receives an update with a higher sequence number for a destination, it knows to update its routing table, ensuring up-to-date routes. “*When there are multiple routes to a destination, a node will choose a route with the highest destination sequence number* “. (Ali, Liu, Chaozhu, & Adnan, 2018).

While DSDV is a good example of a table-driven routing protocol, it has plenty of downsides when implemented in a mesh topology. The frequent routing table updates lead to increased network resource usage, especially when implemented on a large scale. Therefore, other table-driven protocols like OLSR and BATMAN that are effective in MWMNs, are better suited.

## 3.2 B.A.T.M.A.N (Better Approach To Mobile Ad hoc Networking)

B.A.T.M.A.N, analogues to DSDV, is another table-driven routing protocol. It was originally created to replace OLSR (Optimized Link State Routing) and had its focus on wireless ad-hoc networks. The algorithm is designed to deal with unreliable links, which is often the case for links in mobile wireless mesh networks (Open Mesh).

In simple terms, B.A.T.M.A.N’s algorithm can be explained as follows. *Each node transmits OGMs (originator messages) to inform neighboring nodes about its existence.* *OGMs contain at least the address of the originator, the address of the node transmitting the packet, a TTL (time to live) and a sequence number* (Open Mesh). OGMs contain a sequence number, given by the originator of the OGM, so that the algorithm can easily find out if the OGM has been found. “*Each node re-broadcasts each received OGM at most once and only those received from the neighbor which has been identified as the currently best next hop (best ranking neighbor) towards the original initiator of the OGM.”* (Open Mesh).

What about determining the best route to the destination node? B.A.T.M.A.N does this by using the originator messages. By analyzing the OGM, a node can find out the path the data has taken and from there the node must decide which node to forward the data to. This is done by taking multiple factors such as signal strength, latency, packet loss or throughput into consideration. This is repeated until the destination node is reached.

Here is a summary of how B.A.T.M.A.N works:

1. Each node sends out OGMs that contain important routing information, so that other nodes know about its existence.
2. The nodes that receive the OGMs decide the best ranking node to forward this data to.
3. Step 2 is only done once for each node until the destination node is reached.

These three general steps ensure that the data being transferred reaches its destination as fast as possible, by choosing the safest (least packet loss) and fastest route.

# Current and potential future developments

There are many fields in which MWMNs have made an impact in society. One of which is avoiding government restrictions on internet use. FireChat was a mobile app that utilized wireless mesh networks to allow communications between smartphones, peer-to-peer via Bluetooth. All of this without an internet connection. It was mostly used by protestors to go off the grid from mainstream internet (BBC NEWS, 2014).

Another real world example is Cisco’s wireless mesh networking which provides flexible deployment options for outdoor wireless connections (CISCO, u.d.). This technology can be applied in enhancing smart cities, by enabling public Wi-Fi hotspots, sensor devices, and video surveillance.

The future for MWMNs is promising and bright. With the advancements being made in AI and machine learning, advanced algorithms can be made use of for optimization and managing networks. This can possibly be done by improving routing decisions based on AI powered predictions to avoid faulty connections.

As the availability of 5G increases, MWMNs stand to benefit. Reduced latency, increased speed and increased capacity bring substantial improvements to MWMNs. With every leap in generational iterations of wireless communication technologies, MWMNs will keep on improving. If this trend continues, there might come a time when wired connections become obsolete.

# Conclusion

In conclusion, mobile wireless mesh networks have a variety of real world use cases that show their immense value. From enhancing connectivity in smart cities to establishing a communication network from other planets, the versatility of MWMNs is outstanding. This is a technology whose best days likely lie ahead, and it presents the opportunity for further improvements.

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