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Trends in Computer Science and Information Technology

ISSN: 2641-3086 DOI: https://dx.doi.org/10.17352/tcsit

Mini Review

MANETs: How are they evolving to support multimedia communication?

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Received: 06 November, 2020
Accepted: 20 November, 2020
Published: 21 November, 2020

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Keywords: Mobile ad hoc networks; Multimedia transmission; QoS support; Multipath routing; Energy-efficient cross-layer optimization; Cooperative MAC protocols

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Abstract

This short paper discusses critical issues of multimedia over Mobile ad hoc Networks (MANETs) focusing on the Quality of Service (QoS) support for wireless multimedia transmission. The paper explains how MANETs are evolving to support multimedia communication. In particular, it briefly presents some novel approaches that can improve the performance of MANETs when multimedia transmissions take place.

Introduction

A Mobile ad hoc Network (MANET) is a dynamic network that has mobile radio autonomous nodes arranged in a mesh topology (Figure 1). These nodes communicate with each other without any infrastructure and form a multi-hop radio network without a central controller [1].

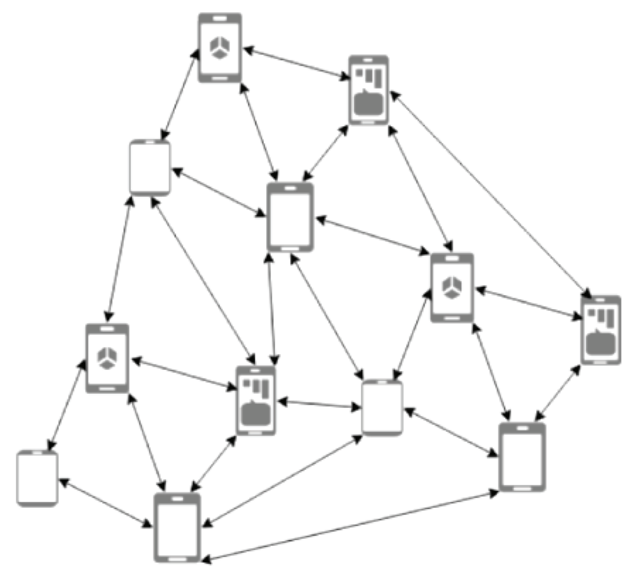

Figure 1: A mobile ad hoc network (MANET).

MANETs are deployed instantly in emergency situations like natural disasters and battlefields. This happens because the nodes of a MANET can communicate with each other without any infrastructure. In such emergency situations, it is important to offer video services for end-users (e.g., search and rescue teams, and first responders) [2]. In MANETs, it is also vital to provide adaptive multimedia transmission to preserve the desired *Quality of Service* (QoS)/*Quality of Experience* (QoE) levels despite the network situation [3]. The following set of network parameters determines service performance:

Throughput: It is the efficient data transfer rate measured in bits per second (bps). It is noteworthy that video services and applications require a minimum rate of throughput.

Latency: It is the end-to-end delay between two points. The first point is the time the data are sent from the source (origin), while the second point is the time that data have been received at the destination.

Jitter: It is the delay variation. During end-to-end transmission, the data packets experience different delays, and thus jitter occurs.

Packet loss: Many causes such as transmission errors, link failures, and network congestion can lead to packet (information) losses. In a MANET, there are variations in channel conditions that enable a large number of transmission errors.

Citation: Kanellopoulos D (2020) MANETs: How are they evolving to support multimedia communication? Trends Comput Sci Inf Technol 5(1): 077-081. DOI: https://dx.doi.org/10.17352/tcsit.000028

Availability: A network with large availability implies that this network can offer services to the end-users for a large percentage of the time.

Reliability: According to IEEE, reliability is described as "the probability that a system will perform its intended functions without failure, within design parameters, under specific operating conditions, and for a specific period of time."

In a MANET, nodes are moving continuously. It is difficult to maintain communication sessions between the source and destination nodes as routes often fail, and this enables re-computations for finding the optimal routing paths. The topology of MANET changes dynamically. To feed the routing algorithm, every node must maintain critical state information such as the information of packet loss rate, delay, jitter, stability, and distance for each link. Because of the changes in the topology, this state information is inherently imprecise. An additional aggravating reason is that the resources (e.g., bandwidth, battery, processing, and storage) in the network are limited. These unusual characteristics of MANETs make difficult QoS provision. As a result, multimedia communication over MANETs becomes difficult. Recently, many research efforts have been made to address important design issues in MANETs such as:

- Effective QoS-based routing protocols [4-6].
- Efficient congestion control methods [7].
- Effective time-division multiple access (TDMA) scheduling algorithms that ensure QoS provisioning by minimizing the end-to-end delay and drop rate [8].
- Video streaming techniques over MANETs [9].
- Development of tools to evaluate MANET performance.

Ref. [4] summarized current solutions on QoS routing and resource reservation mechanisms to provide multimedia transmission over MANETs. From another perspective, Ref. [5] discussed critical issues in power-based routing, while Ref. [6] surveyed energy-efficient routing techniques with QoS assurances for MANETs. Ref. [8] provided a survey of scheduling techniques for MANETs, while Refs. [10,11] surveyed the existing power-aware optimization solutions for MANETs.

The contribution of this short paper is to discuss some novel approaches that can be adopted in the design and implementation of MANETs in order to improve their performance.

MANET characteristics and multimedia communication

MANETs differ from the wired networks as they possess many and unique characteristics. These characteristics are (1) frequent link breakage due to node mobility; (2) high channel error-rate; (3) harsh link-layer contentions, and (4) different path properties such as delay, bandwidth, and loss rate. A MANET also has no central controller, and each node must preserve the required state information (delay, jitter, loss rate, stability, and distance for each link) in order to feed routing algorithms. As we already said, this state information is inherently imprecise. It is concluded that the QoS provision and the transmission of video data packets over the network become difficult [3]. The main characteristics of MANETs can be summarized as follows:

***Dynamic network topology*:** The mobility of the nodes results in some wireless links being broken while others come out. The performance of the routing protocols for MANETs depends on this key characteristic. Consequently, current error control methods such as Automatic Repeat request (ARQ) and Forward Error Correction (FEC) must be adapted to lodge the harsh transmission impairments for satisfactory video transport and the frequent link failures.

***High BER*:** Wireless channels have a higher bit error rate (BER). Multipath fading and interference are the main factors that contribute to this problem. The video quality gets worse when important packet losses and bit errors occur.

***Multi-hop communication*:** This multi-hop characteristic worsens the QoS of the communication session. In an end-to-end connection, more than a few wireless connections are present, and the links exhibit dissimilar characteristics.

***Bandwidth limitation*:** In MANETs, the available bandwidth is very scarce, while the capacity of the network varies with the changing environment.

***Asymmetry*:** The characteristics of each node are dissimilar, and thus we have different path properties such as delay, bandwidth, and packet loss rate.

***Limited energy capacity*:** In a MANET, mobile devices (nodes) operate using the accumulated energy in batteries. These batteries have a lifetime constraint. Therefore, the whole network is energy-limited, and power consumption determines the performance of MANET. The average power consumption in the whole network consists of the processing power and transmission power at mobile devices. It is difficult to keep a high video quality and simultaneously to minimize the average power consumption because these trade-offs are conflicting objectives. In particular, high processing power must be consumed in the source coder to obtain high video quality. From another viewpoint, high transmission power is required because of the interference and transmission impairments occurred in MANETs.

***The need for optimization of energy consumption*:** Extra traffic intensity is generated when a video is transmitted over MANET. This video data traffic notably increases the energy exhaustion of mobile devices because the network traffic intensity level is greater than before [11]. Precisely, during the rapid growth in video traffic, higher packet losses, and excessive network delays occur. This eventually increases energy consumption and reduces QoS performance [11]. In fact, congestion in the network takes place. Congestion causes escalated buffer usage over the available network path, leading to higher packet losses throughout the case of the unavailability of network resources [7]. It is concluded that power-aware optimization routing protocols are vital in MANETs [10]. In [12], a new

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routing protocol, called "*Ad Hoc On Demand Multipath Distance Vector with the Fitness Function*" (FF-AOMDV) is proposed. FF-AOMDV uses the Fitness Function method to optimize power consumption in multipath routing. In particular, the Fitness Function can discover the optimal path from the source node to the destination node in order to reduce the power consumption in multipath routing.

***Cooperation*:** During the establishment of route paths among nodes, all nodes are obliged to participate. However, some nodes do not cooperate as they deny lending their resources for communications purposes among other nodes.

The implementation of video services with sufficient QoS levels is obstructed by the above inherent characteristics of MANETs [3]. To confront this problem, many QoS provisioning architectures and routing protocols have been proposed. The majority of these architectures and protocols take into account the optimization problem of energy-consumption and are based on a Cross-Layer Design (CLD). A CLD permits the interactions between different non-adjacent layers i.e., it permits the sharing of critical information among the layers. Architectures or routing protocols that adopt a CLD can offer improved network management in terms of energy consumption, quality of service, and other performance parameters. We remind that the conventional OSI-layer design results in redundancy within layered wireless protocols and forbids the sharing of critical information among non-adjacent layers.

Novel approaches to improve MANET performance

Hereafter, we present some approaches [10] invented to improve the performance of MANETs.

Cooperative Medium Access Control (MAC) protocols for MANETs

Among a pair of nodes, a wireless transmission is considered as interference in other (third) nodes (terminals). *Cooperative Communication* (CC) [13] makes use of close terminals to relay the overhearing information to achieve performance gains. Third nodes/terminals receive and process this wireless transmission for performance gains. In addition, nodes exploit cooperatively the wireless channel. The performance of a MANET can be improved by applying cooperative transmission [14]. A Cooperative MAC (CMAC) protocol enforces a fair transmission capability to all nodes by handling the complex medium access interactions made by transmissions. An effective CMAC protocol must take into account the medium access layer interactions and signaling overhead due to cooperation. If not, the end-to-end performance cannot be improved by exploiting only the performance gain during the PHY (Physical) layer cooperation. The cross-layer distributed energy-adaptive location-based CMAC protocol (DEL-CMAC) [14] is a novel CMAC protocol that enhances the performance of MANETs in terms of energy efficiency and network lifetime. In [15], another new CMAC protocol for MANETs is proposed. It is called "network Lifetime Extension-Aware CMAC" (LEA-CMAC) and improves network performance through the cooperative transmission. LEA-CMAC completes a multi-objective target orientation to prolong the network lifetime. The optimization problem for extending the network lifetime is formulated by taking into account symmetric and asymmetric transmit power rules [15]. In particular, a distributed relay selection process selects the optimum retransmitting node among the qualified nodes (relays). During such selection, the transmit power of the node, the sufficient residual energy after cooperation, and a high cooperative gain are taken into account. "The LEA-CMAC protocol can obtain a multi-objective target orientation by exploiting an asymmetric transmit power rule to improve the network performance" [10].

Multipath routing based on hybrid modeling

A multipath routing protocol can establish a routing path with much longevity if this routing protocol is based on the predicted nodes' positions. However, the majority of the conventional prediction methods are based only on the past locations of the node. For estimating the exact node location, new hybrid prediction methods are required. Such hybrid methods will be based on the temporal and spatial characteristics, regarding the neighborhood of the node, in order to predict the locations of nodes. For this task, these methods can use soft computing approaches. In particular, "Machine Learning (ML) algorithms can be trained by using features extracted from mobility patterns. The future locations of the node can be obtained by using this ML predictor" [10]. For example, in [16], the mobility prediction method is based on an extreme learning machine. Potential node locations, movement, and velocity can be predicted because each node in the network is aware of its position, direction of movement, and velocity. The routing protocol is adjusted to select the next-hop using these predicted future distances. Clearly, the training volume determines the effectiveness of the hybrid method. The node mobility is predicted using the past information of the neighbor nodes. However, this implies that neighbor nodes exchange a large amount of data packets concerning past information. In [17], the multipath routing protocol has improved routing performance because it avoids such large packet overhead. This is accomplished as it uses estimated probability locations with path diversion at required places along the path.

Fuzzy-logic support in multicast routing protocols

Group-oriented applications (e.g., multicasting video over MANET) use multicast flows in which the delivery of video content requires a sufficient QoS. These applications need multicast on-demand routing protocols that select optimal multiple routes to a group of destination nodes. This selection process is based on tables that can use a fuzzy set of rules. The performance of multicast routing protocols can be improved by combining the fuzzy-logic support with the Cross-Layer Design (CLD) concept. For example, the Cross-layer optimized Multicast Route finding Protocol (C-MRP) [18] is integrated with a light fuzzy-logic set of rules for selecting optimal multiple routes to a set of destination nodes using the available network bandwidth, route stability, and node-to-node delay. The C-MRP multicast routing protocol is better than the current multicast routing protocols [18]. Another cross-layer

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based, lightweight, reliable, and secure multicast routing protocol for MANETs is proposed in [19].

Hybrid optimization algorithms for topology management in cluster-based MANETs

In hierarchical network topology, mobile nodes are formed into *Clusters* in agreement with explicit application requirements. Every cluster has one *Cluster-Head* (CH) elected by the cluster members. The most important task of a CH is to gather sensed information from the cluster members (sensor nodes). For this reason, a CH must have higher power/energy than the cluster members. New optimization algorithms are also required for making efficient clustering and adjusting power and energy parameters. These optimization algorithms use techniques that manage the network topology. The management of the network topology requires the construction of a graph that is equivalent to the real MANET. Then, the optimization algorithm can perform the clustering of this graph to make an optimal CH. To adjust power, the optimization algorithm can be based on an *objective function* that considers some factors that involve battery power, connectivity, node mobility, link lifetime, and distance. The Chronological-Earth Worm optimization Algorithm (C-EWA) [20] is an example of such an optimization algorithm. C-EWA performs effective clustering and regulates power and energy parameters using topology management.

Enhanced routing protocols and congestion control mechanisms using the ICN paradigm

Information-Centric Networking (ICN) is a networking paradigm for the future Internet architecture that provides traffic optimization [21]. ICN decouples content from hosts and provides the ability to retrieve a content object by its identifier (name). In this way, ICN addresses IP network limitations in supporting content distribution and information access. A promising ICN-based architecture is the Named Data Networking (NDN) architecture that deals with the growing traffic demands on the Internet [22]. The central characteristic of the NDN network architecture is the "named content" (or data) and not the "end-host". Based on the named content, NDN can realize fast content retrieval and delivery. In NDN, mobility of nodes and multi-access are norm characteristics, while connectivity may well be intermittent. Data also do not depend on location, application, storage, and means of transportation. This characteristic of NDN facilitates in-network caching and replication of content. NDN supports name resolution, dynamic routing, content caching, and traffic optimization. Recently, NDN has been evolving as a suitable network stack solution for MANETs [23]. The synergy between NDN and MANETs can be exploited to improve the performance of dynamic content routing and congestion control mechanisms. NDN is an ideal architecture for deploying effective congestion control for MANETs [24]. NDN provides new points of view on the communication in MANETs because routing protocols can be based on names. Authentic content can be stored and cached by any node in the network because each content object has a unique name and is signed. When a wireless link (that directs to a certain content source) breaks, this content can also be retrieved from a nearer node that offers the same content copy. This implies that it is not required to create a new path to the initial content source. As a result of caching, retransmissions do not need to be performed over the entire path when collisions occur. Retransmissions need only to be performed over the link where the collision occurred.

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