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A Study onWireless Ad Hoc Networks

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***Abstract**:*

A wireless ad hoc network is a collection of wireless nodes that can dynamically self-organize into an arbitrary and temporary topology to form a network without necessarily using any pre-existing infrastructure. These characteristics make ad hoc networks well suited for military activities, emergency operations, and disaster recoveries. Nevertheless, as electronic devices are getting smaller, cheaper, and more powerful, the mobile market is rapidly growing and, therefore, the need of seamlessly internetworking people and devices becomes mandatory. New wireless technologies enable easy deployment of commercial applications for ad hoc networks. This paper presents an overview of medium access control (MAC), routing, and transport in wireless ad hoc networks.

Keywords

MAC, Ad Hoc, Internetworking, TCP, Routing

1. Introduction

Wireless networks are being increasingly used in the communication among devices of the most varied types and sizes. Personal computers, handhelds, telephones, appliances, industrial machines, sensors, and others are being used in several environments, such as residences, buildings, cities, forests, and battlefields. Different wireless network standards and technologies have appeared in the last years to enable easy deployment of applications. The deployment of wireless networks where there is no infrastructure or the local infrastructure is not reliable can be difficult. Ad hoc networks have been proposed in order to solve such problems. A wireless ad hoc network is a collection of wireless nodes that can dynamically self-organize into an arbitrary and temporary topology to form a network without necessarily using anypre-existing infrastructure. In ad hoc networks, each node may communicate directly to each other. Nodes that are not directly connected communicate by forwarding their traffic through intermediate nodes. Every ad hoc node acts as a router. The main advantages of ad hoc networks are flexibility, low cost, and robustness. Ad hoc networks can be easily set up, even in desert places and can endure to natural catastrophes and war. These characteristics make ad hoc networks well suited for military activities, emergency operations, disaster recovery, large scale community networks, and small networks for interaction between meeting attendees or students in a lecture room.

The design of a wireless ad hoc network has to take into account several interesting and difficult problems. Traditional wireless communication problems related to the physical medium, such as low transmission rate, high bit error rates, noise, limited range, and significant variation in physical medium conditions, must be overcome. In the MAC sublayer, the difficulty of collision detection and the hidden and the exposed terminal problems demand new medium access algorithms. Moreover, as wireless ad hoc nodes may move arbitrarily and the status of the communication links between the nodes may vary, routing protocols proposed for wired networks are not suited for operation in wireless ad hoc networks. Several routing protocols have been proposed to cope with the various challenges of ad hoc networks. At the transport layer, TCP-like transport protocols also present several problems when used on wireless networks. High bit-error rates and frequent route failures reduce TCP performance, demanding modifications to TCP or the design of new transport protocols.

Other issues are also important when designing a wireless ad hoc network. The uncontained shared medium creates difficult challenges for securing the wireless network. On the other hand, the use of mobile devices equipped with radio interfaces turns energy conservation an important issue. Additionally, peculiarities of the wireless technology used, such as multiple channels and directional antennas, may improve the performance of the network but must be carefullyconsidered in redesigning some of the protocol layers. This paper is organized as follows. Section 2 presents different MAC protocols designed for wireless ad hoc networks. Section 3 describes Bluetooth and IEEE 802.11, the most widespread technologies for wireless ad hoc networks. Section 4 compares the main routing protocols for ad hoc networks.

2. Medium Access Control Protocols

The design of a suitable Medium Access Control (MAC) protocol is an important issue for an ad hoc network. The protocol must deal with channel constraints, attenuation, and noise, whereas provide an efficient medium access considering requirements, such as quality of service (QoS), low energy consumption, fairness, and scalability. MAC protocols for wireless networks can be classified as contention-free or contention-based, depending on the medium access strategy [1]. The contention free schemes pre-define assignments to allow stations to transmit without contending for the medium, e.g., TDMA, CDMA,

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FDMA, polling, and token-based. Contention-free mechanisms are normally employed to provide bounded end to-end delay and minimum bandwidth, privileging delay sensitive applications such as audio and video streams. Bluetooth personal area networks employ a master-slave MAC mechanism. On the other hand, contention-based schemes are more appropriate for sporadic data transfer on mobile networks due to the random and temporary nature of the topologies. Wi-Fi local area networks in their ad hoc mode employ contention-based MAC protocols.

3. ENABLING TECHNOLOGIES

Bluetooth and IEEE 802.11 are the main technologies for implementing wireless ad hoc networks [2]. In the following subsections, we give a brief overview of the MAC sub-layer and some physical layer characteristics of Bluetooth and IEEE 802.11.

A) Bluetooth:

Bluetooth is a wireless technology that is being used to deploy personal area networks and adopted as IEEE 802.15.1 standard [3]. Most Bluetooth products are compliant with the 1.1 specification [4]. The Bluetooth architecture consists of a basic unit called piconet and of scatternets. A piconet is an ad hoc network formed by a master and slave's devices. A device can be a master or a slave, but not both at the same time. The master is the device that establishes the piconet and the slaves are the other devices that belong to the piconet. The master informs the slaves the logical addresses to be used, when the slaves can transmit and for how long and what frequencies must be used in transmission. Communication is always between a master and one or more slaves (point-to-point or point-to-multipoint). There is no direct communication between slaves. A piconet is composed of a master and up to seven active slaves. Moreover, there may be up to 255 inactive devices in the network, in a low-power state. The maximum number of active devices could limit the applicability of Bluetooth, but a Bluetooth network can be extended by the interconnection of piconets. In this case, the network is called a scatternet and the piconets are interconnected by bridge nodes. The bridge between the piconets can have the role of slave in all piconets to which they belong or of master in one piconet and slave on the others. A bridge cannot be master in more than one piconet, because the master is the unit that establishes the frequencies to be used in communication. Figure 1 shows an scatternet example in which the bridge node is a master in one piconet and a slave in the other piconet. In order to separate master and slave transmissions, Bluetooth uses a Time Division Duplexing (TDD) scheme, with a 625 μs slot time. The master begins its transmission in even slots and slaves transmit in odd slots. Frames can be one, three or five slots long, depending on the frame type.

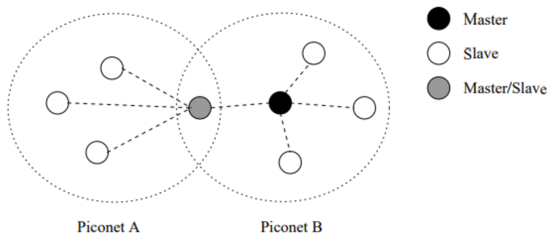

Fig. 1. Scatternet example

B) IEEE 802.11

IEEE 802.11 [5], also known by Wi-Fi (Wireless Fidelity), is the most widespread wireless technology. The 802.11 family includes several standards, e.g., IEEE 802.11b, IEEE 802.11a, and IEEE 802.11g, which differ in the physical layer. The IEEE 802.11 MAC protocol specifies two medium access algorithms: Distributed Coordination Function (DCF) and Point Coordination Function (PCF). DCF is a distributed mechanism in which each node senses the medium and transmits if the medium is idle. On the other hand, PCF is a centralized mechanism where an access point controls medium access. Therefore, this mechanism is designed for infrastructure networks. The DCF function uses Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) to control medium access (Figure 2). A station that wants to transmit first senses the medium. If the medium is idle for at least a time called Distributed Inter-Frame Space (DIFS), the station transmits. Otherwise, if the medium is busy, the transmission is postponed until a DIFS period after the end of the current transmission. After deferral, a back off process is initiated. A station chooses a random number between zero and the Contention Window (CW) size and starts a back off timer. This timer is periodically decremented by a slot time after the medium is sensed idle for more than DIFS. The back off timer is paused when a transmission is detected. If the medium gets idle for DIFS again, the station resumes its back off timer. When the timer expires, the station sends its frame.

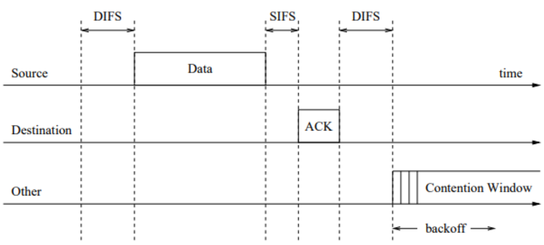

Fig. 2. Transmission of a data frame using the IEEE 802.11 protocol

A Cyclic Redundancy Check (CRC) is used for error detection. If the frame seems to be correct, the receiver sends an acknowledgment frame (ACK) after sensing the medium idle for a period of time called Short Inter-Frame Space (SIFS). SIFS is smaller than DIFS to prioritize the access and reception of acknowledgment frames over data frames.

4. ROUTING PROTOCOLS

According to the routing strategy, ad hoc routing protocols fall into two categories: topology-based and position-based protocols. Topology-based routing protocols find a route from a source to a destination according to the metrics of the network links. Networks that employ topology-based protocols forward packets based on the address of the destination node. On the other hand, position-based routing protocols do not require the establishment or maintenance of routes. Here, the idea is to obtain the information about the geographical position of the destination and find the best way to forward packets to this position.

A) Topology-Based Routing

Topology-based routing protocols rely on the status of the network links to compute a route from a source to a destination. Thus, every node of the network must exchange routing information to maintain routing tables up to date. Topology-based protocols can be further divided into proactive and reactive protocols

Proactive routing: protocols work like a classical Internet routing protocol. They share routing information even if there are no specific requests for a route to maintain consistent and up-to-date routes from each node to every other node in the network. Proactive protocols require that each node stores a routing table and responds to changes in network topology by propagating update messages throughout the network to maintain a consistent network state.

Reactive Routing: Reactive, or on-demand, routing protocols operate only when there is an explicit request for a route. This strategy only creates routes when desired by a source node. When a node requires a route to a destination, it initiates a route discovery process within the network. This process is completed when a route is found or when all possible route permutations have been examined. Once a route has been established, it is maintained by a route maintenance procedure until either the destination becomes inaccessible because a link rupture or until the route is no longer needed. Reactive routing significantly reduces the memory consumption in the nodes and only generates control traffic when needed, but it typically floods the network with control messages to discover routes between two communicating nodes. Despite providing fast route discovery, flooding has several inconveniences frequently observed, such as redundancy, contention, and collision [6]. In a typical mobile ad hoc network, the resource consumption caused by control packets has a significant impact because of the low-bandwidth links and power-limited terminals.

B) Position-Based Routing

Position-based routing protocols require that information about the geographical position of the communicating nodes be available. Each node determines its own position using GPS (Global Positioning System) or some other kind of positioning system [7]. In position-based routing, nodes have neither to maintain routing tables nor to exchange routing messages since the packet forwarding is performed based on the position of the destination node, carried by each packet. Then, before sending a packet, it is necessary to determine the position of its destination. Thus, the source node needs to use a location service to determine the position of the destination node and to include it in the destination address of the packet.

5. Transport Protocols

The TCP protocol was designed for wired network with low bit error rate and assumes that data loss is due to congestion. Thus, when the sender transmits a TCP-data segment, it starts a retransmission timeout (RTO), and waits for a TCP acknowledgment from the receiver. When acknowledgments do not arrive at the TCP sender before the RTO goes off, the sender retransmits the segment, exponentially backs off its retransmission timer for the next retransmission, and closes its congestion window to one segment. Therefore, the exponential back off retransmission and the congestion window mechanism prevent the sender from generating more traffic under network congestion. Repeated errors will ensure that the congestion window at the sender remains small, resulting in low throughput. Nevertheless, because of the high bit error rate of a wireless link, TCP-data segments and acknowledgments may be lost without congestion. In this case, the retransmission of the TCP-data segment in error should be done as fast as possible, instead of backing off and closing the congestion window. For mobile wireless networks the negative aspects of these mechanisms are even worse. Mobility and fading cause link failures and, therefore, path disruption. While the routing protocol is finding the new path the TCP recovery mechanism continues retransmitting new copies of the TCP-data segment and exponentially increasing its retransmission timeout. Therefore, the mobile node does not begin receiving data immediately after the new path establishment. As outlined, the main problem that affects the TCP performance is to distinguish errors due to congestion from other errors such as: corrupted data, route failures, etc. Fixed RTO [8] uses a heuristic to distinguish route failures and congestion. When two timeouts expire in sequence, the Fixed-RTO TCP sender assumes that a route failure has occurred. The unacknowledged TCP segment is retransmitted but the timer is not doubled. This proposal is restricted only to wireless networks and does not fit well for combined wired and wireless networks. TCP Detection of Out-of-Order and Response (DOOR) [9] interprets out-of-order TCP segments as route failures.

6. CONCLUSION

The main advantages of ad hoc networks flexibility, low cost, and robustness. New wireless technologies enable easy deployment of commercial applications for ad hoc networks. wepresented an overview of medium access control (MAC), routing, and transport in wireless ad hoc networks.

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