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Study of Topology control and routing in MANET

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ABSTRACT

In Wireless Mobile Ad Hoc Networks (MANETs), energy is a crucial resource. Topology control technology allows network nodes to reduce their transmission power while preserving the network connectivity. A MANET is a non-cooperative system so that only when a node earns its payment, which can cover its cost, the cooperation can be stimulated. The author studied a Truthful Topology Control mechanism (TRUECON) for MANETs to induce the selfish, but rational, network nodes to collaborate. Truth-telling is a dominant strategy in TRUECON. A node needs to reveal its true value in order to obtain the maximum expected utility.

Keywords: topology, routing, MANET, TRUECON, wireless, network.

INTRODUCTION

For the different structure TCP do not work properly with the specific effects occurring in MANETs. This is because TCP has originally been designed for the Internet, a network with different properties. As a consequence, appropriate congestion control is widely considered to be a key problem for MANETs. A mobile ad-hoc network is a collection of mobile nodes forming an ad-hoc network without the assistance of any centralized structures. These networks introduced a new art of network establishment and can be well suited for an environment where either the infrastructure is lost or where deploy an infrastructure is not very cost effective.

The popular IEEE 802.11 "WI-FI" protocol is capable of providing ad-hoc network facilities at low level, when no access point is available. However in this case, the nodes are limited to send and receive information but do not route anything across the network. Mobile ad-hoc networks can operate in a standalone fashion or could possibly be connected to a larger network such as the Internet. Mobile ad-hoc networks can turn the dream of getting connected "anywhere and at any time" into reality. Typical application examples include a disaster recovery or a military operation. Not bound to specific situations, these networks may equally show better performance in other places. As an example, we can imagine a group of peoples with laptops, in a business meeting at a place where no network services is present. They can easily network their machines by forming an ad-hoc network. This is one of the many examples where these networks may possibly be used.

Topology control technology let network nodes in a MANET adjust their transmission power in order to reduce their neighbor sets. When every node transmits using its maximum power, the network graph is denoted as G(V, E). The graph derived by topology control is G0 (V, E0), which is a subgraph of G(V, E), G0 (V, E0) $\subseteq$ G(V, E). G0 must preserve the connectivity of G. In other words, if a pair of nodes u and v is connected in G, they should be connected in G0 too. In G0 , the node degree is lower than in G. This is desirable in MANETs because the short the edges, the less power a node uses to transmit and the smaller area the radio interference can affect. Furthermore, the wireless network capacity is closely related to the node degree. The network throughput drops quickly as the network size increases.

Comparing the power-efficient routing, topology control is a pro-active method to reduce power consumption and radio interference. Forming a power-efficient network topology without degrading the network connectivity needs the collaborations among all the nodes. The existing topology control algorithms assume that if a network node receives a service request it always follows the pre-defined protocol without any bias. However, this assumption cannot be valid in MANETs anymore. As a MANET is formed on the fly, there is not a central authority to regulate the behaviors of each node. A node is free to join and leave without notification and permission. Moreover, most of the network nodes are battery-powered and have only a limited energy reserve. Forwarding data packets incurs power consumption at the intermediate nodes without obvious benefit.

Features of Mobile Ad-hoc Networks

MANETs is an IEEE 802.11 framework. It is an interconnected collection of wireless nodes where there is no networking infrastructure in the form of base stations, devices do not need to be within each other‘s communication range to communicate, the end-users devices also act as routers, nodes can enter and leave over time, data packets are forwarded by intermediate nodes to their final destination.

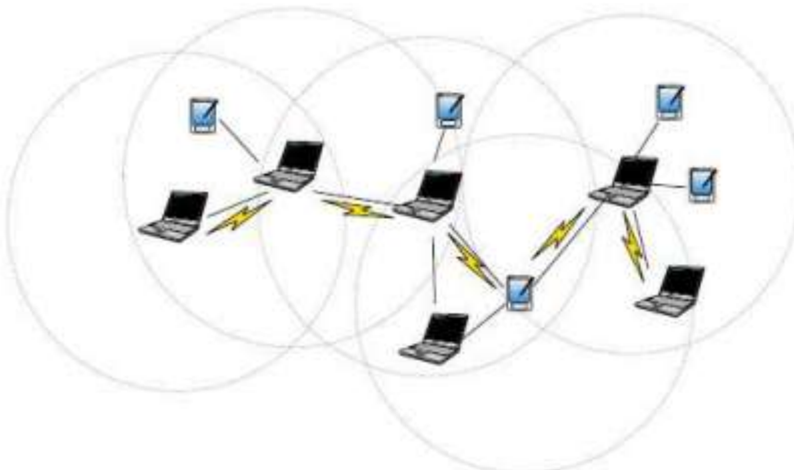

Figure 1: Mobile Ad-hoc Networks (MANETs)

Characteristics of MANETs

Mobile ad hoc network nodes are furnished with wireless transmitters and receivers using antennas, which may be highly directional (point-to-point), omni directional (broadcast), probably steer able, or some combination thereof. At a given point in time, depending on positions of nodes, their transmitter and receiver coverage patterns, communication power levels and co-channel interference levels, a wireless connectivity in the form of a random, multihop graph or "ad hoc" network exists among the nodes. This ad hoc topology may modify with time as the nodes move or adjust their transmission and reception parameters.

The characteristics of these networks are summarized as follows:

- Communication via wireless means
- Nodes can perform the roles of both hosts and routers
- Bandwidth-constrained, variable capacity links
- Energy-constrained Operation
- Limited Physical Security
- Dynamic network topology
- Frequent routing updates

STATE OF THE ART

What are MANETs and why are they so interesting? How do the routing protocols operate in this kind of networks? This section gives an overview of these as well as a study to understand which routing protocol is better to use for each environment.

Mobile Ad-Hoc Networks

Mobile Ad-Hoc networks or MANET networks are mobile wireless networks, capable of autonomous operation. Such networks operate without a base station infrastructure. The nodes cooperate to provide connectivity. Also, a MANET operates without centralized administration and the nodes cooperate to provide services. Figure 2. illustrates an example of Mobile Ad-Hoc network.

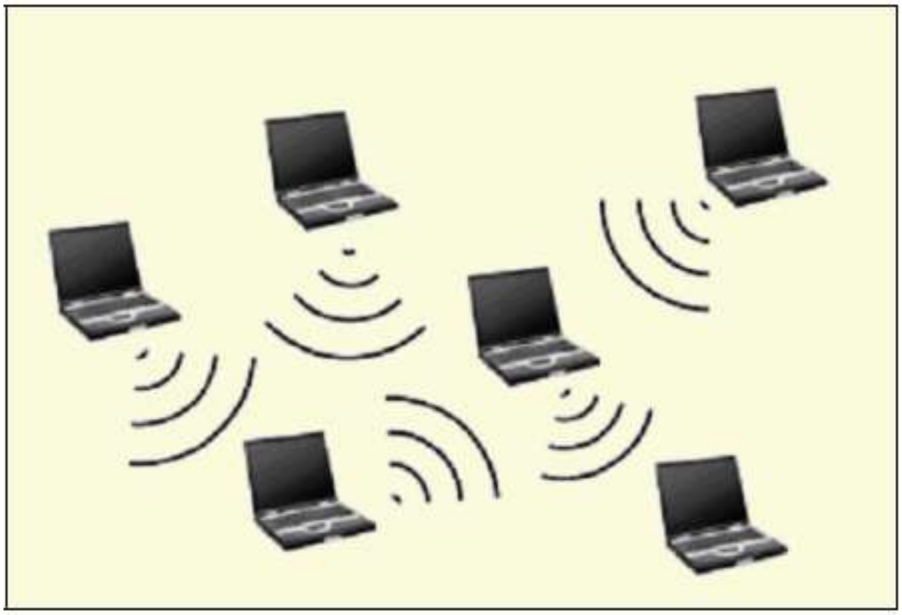

Figure 2: Example of mobile Ad-Hoc network. In a MANET there is no form of centralized administration. All nodes can perform as hosts and as routers. Also the nodes are mobile. Hence, the topology changes constantly.

MANETs can communicate with different networks that are not ad-hoc. Therefore, they can communicate with wired networks creating hybrid networks. In the ad-hoc networks, the mobility of the nodes makes that the topology changes continuously. Hence, a specific dynamic routing protocol for MANETs which discovers and maintains the routes, and deletes the obsolete routes continuously is necessary. The routing protocols for MANETs try to maintain the communication between a pair of nodes (source-destination) in spite of the position and velocity changes of the nodes. To achieve that, when those nodes are not directly connected, the communication is carried out by forwarding the packets, by using the intermediate nodes.

The origin of MANETs begins in the 70's for the military necessity of the interconnection of different hosts. This type of networks was implanted to avoid the need of a central base of communications. With these networks it was expected to transmit information in a fast and stable way as well as to cover the major part of the possible range without the necessity of having a previous infrastructure.

TOPOLOGY AND ROUTING

The nodes mobility makes the topology change continuously and therefore the nodes create and delete links dynamically. The routing is not the same as in the wired networks. In wired networks routers are the central elements. In MANETs, there is no such element, but all the nodes can perform as a router, transmitter or receiver element. Hence, the routing is made by the node executing a specific routing protocol for MANETs.

Basic Route Discovery

When a node sends a packet to a destination, firstly it looks at its Route Cache the routes previously learned. If no route is found in its cache, then the node begins the route discovery process with a Route Request Packet (RREQ) broadcast. This packet includes the destination address, the source address and an identification number (request id). Each node receiving the RREQ, looks for the destination in its cache. If it does not know the route to the destination, it adds its address to the 'route record' in the RREQ and propagates it by transmitting it as a local broadcast packet (with the same request id). To limit the number of RREQ's, if one node receiving the RREQ has recently seen another RREQ from the same source, with the same request id, or if it finds its own address in the route record, then it discards the RREQ.

TCP ANALYSIS & PERFORMANCE IN MANETS

Even though TCP ensures reliable end-to-end message transmission over wired networks, a number of existing researches have showed that TCP performance can be substantially degraded in mobile ad-hoc network. Along with the traditional difficulties of wireless environment, the mobile ad-hoc network includes further challenges to TCP. In particular, challenges like route failures and network partitioning are to be taken into consideration. Furthermore, MANET experiences several types of delays and losses which may not be related to congestions, though TCP considers these losses as a congestion signal. These non-congestion losses or delays mostly occur due to the inability of TCP's adaptation to such mobile network. Appropriate cares have to be taken for assessing such losses and also to distinguish them from congestion losses so that TCP can be sensitive while invoking the congestion control mechanism. The next subsections present an analysis of different types of constraints influencing the TCP performance in MANET environment.

Network Partitioning

A network partition takes place when a node departs from the network, resulting in an isolation of some parts of a mobile ad-hoc network. These fragmented portions are defined as partitions. In a MANET environment, TCP considers network partitioning as one of the most imperative challenges which is mainly caused due to mobility or energy-constrained operation of nodes. When the source and the destination of a TCP connection lie in different parts of the network, all transmitting packets are found to be dropped by the network. As a result, the congestion control algorithm will be invoked instantly by the TCP sender. Again, the serial timeouts at the TCP sender can be generated in case of frequent disconnections in the network. This may trigger a longer idle period for the network through which the connection can be re-established. However, the TCP does not found to move from the back off state. An ideal example is illustrated in Figure 3:

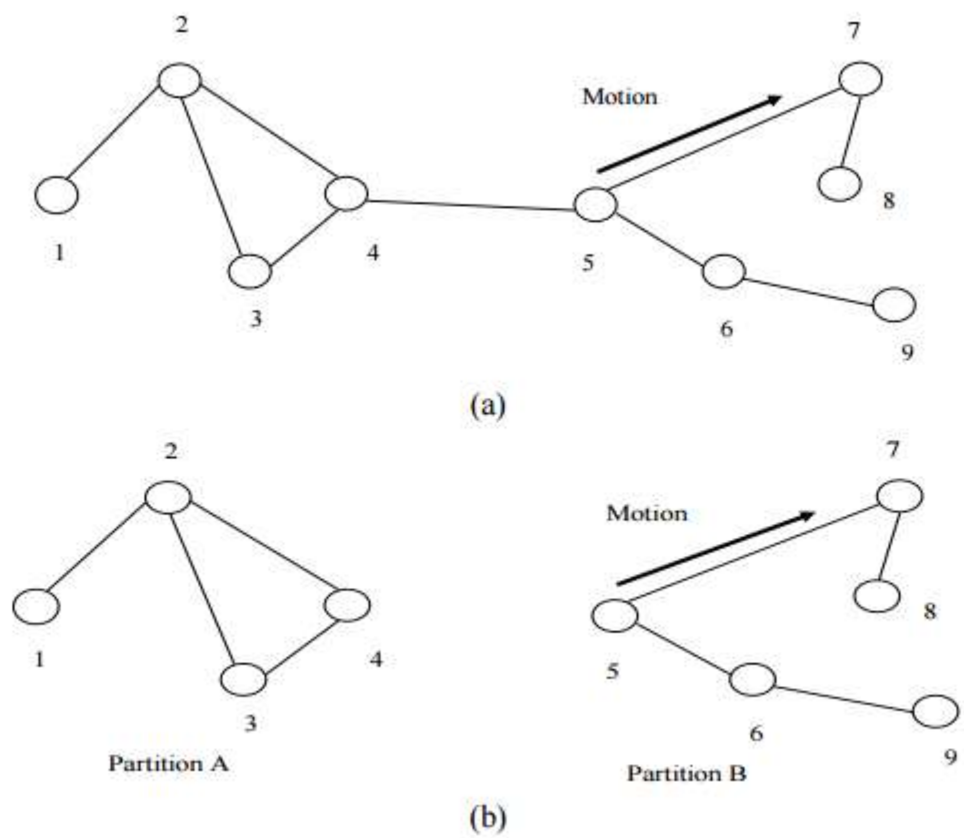

Figure 3: Partition Impact (a) before movement (b) after movement

Evaluation Analysis

It is important to know if indeed, to mix both AODV and OLSR improves each one separately. Besides AODV and OLSR, DSR and ZRP are going to be studied hereafter. DSR is a very important and typical routing protocol for MANETs, and ZRP is hybrid as well as Penaguila. When comparing a new routing protocol with the current protocols making a simulation study is very usual. There are several different simulation programs that can be used for the simulation, like for example:

ns2 [NS_2], GloMoSim [GloMoSim], QualNet [QualNet] and OPNET [OPNET]. The most commonly used software of the four is the ns2 [NS-2]. To programme a routing protocol of these characteristics may involve writing thousands of code lines. Therefore, it was impossible to do this kind of evaluation in so short time. However, in this paper we have discuss in brief how the Penaguila protocol performs under different network settings, and how good it is in comparison with other protocols.

Since it has been impossible to simulate the Penaguila routing protocol, there is no quantitative study of it in this Work. However, for AODV, DSR, OLSR and ZRP there are a lot of quantitative studies. Some results of these reports are included in the following to understand and demonstrate the performance of these protocols. Understanding why they perform in such a way and explaining qualitatively as much as possible all the features, it is possible intuitively to predict how good the Penaguila routing protocol can be.

Quantitative Study of the Existing Protocols

As said before, in this Work there is no simulation of the Penaguila routing protocol. However, it is possible to find a lot of papers studying by means of simulation the performance of AODV, DSR, OLSR and ZRP. In the following, these protocols are going to be analyzed using graphs with the parameters explained before, taken of some papers. To make a performance study it is necessary to define a scenario which is going to be object of the analysis. As it has been said in this work, each routing protocol for MANETs performs better or worse depending on the environment (number of nodes, traffic, nodes velocity, etc.). In this section, results of the [Perf_MIL04] paper (quantitative) are used to discuss (qualitatively) the characteristics of each protocol. This study was made using QualNet. The control values for parameters in experimental groups (or the scenarios defined for the next simulations) are:

Table 1: Control Values for parameters for each experimental group

Parameters/ Group	Size	Density	Hops	Load	Mobility	Sources
Size (nodes)	Varies	50	Varies	50	50	50
Density (m/nodes)	253	Varies	253	253	253	253
Max. Hops	10	10	Varies	10	10	10
Load (bytes/s)	1460/src	23360	17520	Varies	23360	17520
Mobility (m/s)	0	0	0	0	Varies	0
Sources	1/3' rd	16	12	16	16	varies

In all the experiments of [Perf_MIL04] Constant Bit Rate (CBR) application traffic was used with UDP as the transport layer. At the MAC layer, the IEEE 802.11 DCF (Distributed Coordination Function) protocol was utilized, with the IEEE 802.11b radio device with a maximum data rate of 2 Mbps. The radio range was approximately 375. Each experiment occurred within a square terrain dimension. Node placement within the topology is always random and uniform. The node density was chosen to be 253 meters square per node, with the exception of the node density group of experiments for which this value varies. The control values for all parameters in all experimental groups are summarized in table 1. The set of CBR applications for each set of experiments were chosen by randomly selecting the set of sources and destinations from the available nodes using 3 different random seeds. Each point of the graphs of the results is the result of 9 separate simulation runs. The main part of this study is based on [Perf_MIL04], but in those cases that the results of [Perf_MIL04] are not clear enough or when it is necessary to use some additional information, there are extra results from other papers (more references) in order to study in depth the performance of the routing protocols.

CONCLUSION

The technology of mobile ad-hoc networking has received a lot of attention since the wireless networking and the mobile computing devices are now capable of supporting the requirements of this technology. In recent years, a variety of new routing protocols have been developed for MANETs. However, little research on performance evaluation, including any comparative analyses on such protocols is available. On the other hand, TCP optimization in such a network has become a challenging issue because of some unique characteristics of MANETs. Hence, in this paper, a thorough understanding of the MANET routing protocols and TCP versions has been gained through reviews. This review makes contribution in three areas. Firstly, the study undertakes an analysis towards a comprehensive performance evaluation of four IETF standardized routing protocols in a MANET environment. The considered routing protocols are DSR, AODV, OLSR and TORA, covering a range of design choices, including source routing, hop-by-hop routing, periodic advertisement, and on-demand route discovery. Secondly, the study analyzes the performance of the three most widely used TCP variants (Reno, New Reno and SACK) in an ad-hoc environment. In this respect, a review is performed into aspects as to how well these variants respond to different network conditions in a MANET environment, with respect to extension of network size and variation of mobility rate. Finally, an analysis is carried out on the review results of throughput, end-to-end delay, upload response time, download response time and retransmission attempts. These review results have facilitated in determining the most suitable routing protocols and TCP variants that can perform more efficiently and robustly in a mobile ad-hoc network.

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