

IMPACT OF GATEWAY DISCOVERY ON TCP-CONNECTIONS IN MANETS

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ABSTRACT

Mobile ad hoc networks (MANET) can be formed in scenarios where the access to the Internet is demanded. Most of the Internet traffic could be supported by TCP traffic (e.g. HTTP traffic). However, TCP technology needs to be adapted to cope with the different features of the wireless (the MANET node) and the wired (Internet host) mediums. The functionalities for this adaptation could be implemented in the Gateway as it is proposed by TCP-GAP. This new version of TCP is specially designed for MANETs connected to the Internet. Although the evaluation results seem promising, this new technology has been exclusively evaluated in static scenarios. This kind of scenarios represents a simplification of real MANETs where terminals can freely move. Furthermore, static scenarios do not deal with the problem of acquiring or updating the route to the Gateway which connects to the Internet. Our paper focuses on the evaluation of TCP-GAP in mobile environments. In particular, it analyzes the impact of the gateway discovery procedure on the TCP performance by means of simulations. As the simulations show, the gateway discovery procedures, by which mobile nodes update the route to the Gateway, have a significant effect on the asymmetry of the TCP-flows.

KEYWORDS

MANET, Internet, Multihop, wireless, Gateway, Mobile.

1. INTRODUCTION

Mobile Ad hoc NETWORKS (MANET) are composed of wireless devices that communicate without any infrastructure. The communication between two distant nodes (not directly connected) is achieved by intermediate nodes which collaborate in the retransmission of the packets from the source to the final destination. Due to the capability of offering connectivity without any deployed equipment, this technology was initially conceived to work with in military scenarios or environmental disasters. However, the popularity of mobile devices and the growing interest of being connected anywhere and anytime have extended this technology to other applications. For instance, a MANET can be used in a visiting park or a conference venue in an economic way. If we pay attention to these new applications, we can expect that users demand access to the Internet. Furthermore, most of the access is based on TCP (Transmission Control Protocol) connections. In order to interconnect a MANET to the Internet, a conventional Access Router is not sufficient. The Access Router emits Router Advertisement messages [Narten, T et al, 2007] which cannot be propagated as they are generated with link-local addresses [Hinden, R. et al, 2006]. However, these messages are needed by all the nodes in a MANET as they contain the information necessary to enable mobile nodes to generate or acquire an IP address. As a MANET node could be several hops away from the Access Router, a new element is required in order to guarantee that all the nodes know the configuration parameters. This new element is a Gateway. The Gateway is directly connected to the Access Router via a wireless or wired link. It is responsible of generating Modified Router Advertisements (MRA), which are a modified copy of the Router Advertisements created by the Access Router. The main difference is that MRA can be forwarded so all the nodes in the MANET can receive them. Besides, the reception of the MRA messages is used by mobile nodes to create/update or optimize the route to the Gateway, that is, the route to send the packets to the Internet. Taking into account this use, the question is when MRA messages should be generated.

The process by which MRA messages are created differentiates the gateway discoveries. In the global connectivity support [Wakikawa, R. et al, 2006], which is the most popular mechanism to integrate a

MANET into the Internet, there are three types of gateway discovery: reactive, hybrid and proactive. Although some studies have already focused on the impact of the gateway discovery on UDP transmissions, this paper analyzes the TCP performance for the three gateway discovery procedures. In particular, the studied TCP technology includes some techniques to adapt its congestion control to the different mediums (wireless, wired) in an Internet-connected MANET. It is called TCP-GAP (Gateway Adaptive Pacing) [EIRakabawy, S. M. et al, 2008]. TCP-GAP has already been studied in [EIRakabawy, S. M. et al, 2008]. However, these studies are restricted to static scenarios. In this kind of environments, the routes to the Gateway are always active and they are assumed to be statically configured. Thus, the protocol has been evaluated without taking into account the effects of the gateway discovery procedure. Our paper provides an analysis about the performance of TCP-GAP for different gateway discoveries in mobile scenarios. As shown, the main effect of the type of Gateway discovery is the asymmetry provoked on the TCP-flows.

The rest of the paper is structured as follows. Section 2 describes the TCP-GAP protocol. Section 3 explains the functionality of the Global Connectivity support. Section 4 shows the simulation results and the explanations about this performance. Finally, Section 5 draws the main conclusions of our work.

2. TCP IN INTERNET-CONNECTED MANETS

TCP is a technology that offers a reliable transmission for upper layers. In order to guarantee this reliability, each data segment is tagged with a sequence number. The receptor confirms the reception of the datagram using the sequence number in a specific message called ACK (Acknowledgment message). Cumulative acknowledgment is possible so multiple segments can be confirmed with just one ACK message. Additionally, flow and congestion control are also present in TCP technology. Flow control is supported by a window that represents the interval of segments that can be sent while the sender is waiting for their confirmations. Alternatively, the congestion control stands up for the algorithms that avoid congestion in the network provoked by the repeated emission of non-confirmed segments [Allman, M. et al, 1999].

TCP technology is based on the assumption that losses are due to congestion problems. This condition holds in wired networks but in wireless connections losses are mainly caused by interferences. In order to adapt TCP to the wireless scenarios, several versions of TCP have been proposed [Tian Y. et al, 2005]. In the context of Mobile Ad Hoc Networks, TCP must also cope with multihop communications. [Sundaresan, K. et al, 2003] [EIRakabawy, S. M. et al. 2005] are some protocols specifically proposed for MANETs. On the other hand, TCP-GAP focuses on the fact that an Internet-connected MANET deals with the two different mediums [EIRakabawy, S. M. et al, 2008]. To improve the goodput offered by the network, an adaptive transmission rate is used in the mobile nodes and in the Gateway. Assuming 802.11-based connections, the protocol states that the interferences in a single hop can be avoided if a data segment is transmitted when the previous one has already reached the next four hops (this condition is set taking into account the hidden terminal effects). Therefore, the estimation of the four-hop propagation delay (FHD) of TCP segments constitutes the basis of the algorithm that adapts the transmission rates.

In a similar way, the Gateway adapts its transmission rate to the estimated FHD. In contrast, this estimation is particular for each flow. The Gateway stores the received segments in an internal buffer and retransmits them according to the estimated rate (which is based on the measured RTT for each flow). For more details about the setting of the transmission rate, please refer to [EIRakabawy, S. M. et al, 2008].

3. GATEWAY DISCOVERY

The key element to connect a MANET to the Internet is a Gateway. The gateway has two main functionalities. Firstly, it distributes the configuration parameters in the network. This is done by the emission of specific messages called Modified Router Advertisement (MRA) messages. Additionally to the acquisition of the configuration parameters, these messages are employed by the mobile nodes to create, update and/or optimize the route to the Gateway, that is, to the Internet. Additionally, the Gateway routes the packets that the Access Router receives in the MANET. Conventional Access Routers do not implement any ad hoc routing protocol so a Gateway is necessary to discover and route the packets in the MANET.

The Global Connectivity support is the most popular scheme to integrate a MANET into the Internet. In this mechanism, three gateway discoveries are described: reactive, proactive and hybrid. In the reactive scheme, the mobile nodes that need to send a packet to the Internet and it does not hold a valid route to the gateway, generates a Modified Router Solicitation (MRS) message. This message is broadcast in the network and when received by the Gateway, it replies with a unicast MRA message. This response is propagated just in the path from which the Gateway has received the MRS. In contrast, the proactive gateway discovery is based on the periodic emission of broadcast MRA messages each T seconds. Thus, mobile nodes periodically receive a copy of a MRA message and, in turn, periodically update the route to the Gateway. Along the interval of emission of the MRA message, the mobile can freely move. This movement could make the stored routes stale so a mobile node needing to route the packets to the Internet acts reactively. Finally, the hybrid scheme combines the two previous mechanisms. In an area close to the Gateway, MRA messages are periodically broadcast. However, those nodes that are outside this area (defined by the TTL parameter) are forced to know the routes to the Gateway in a reactive way.

4. EVALUATION OF THE IMPACT OF GATEWAY DISCOVERY

The goal of this paper is to evaluate the impact that the type of gateway discovery provokes on TCP performance. For this task, we use a comparison approach so that the goodput offered by TCP-GAP is measured for the three types of gateway discovery (reactive, proactive and hybrid) under the same conditions. In order to repeat the experiments under the same environmental settings, we have conducted our study by means of simulations. In particular, NS-2 was employed [Fall, K. et al, 2010].

The tests were performed in a squared area of $1000 \times 1000 \text{ m}^2$. The gateway is placed in the center of the area, that is, at (500,500) m. One TCP connection is established in every simulation. The TCP traffic is from a mobile node to the Internet host which is acceded through the Gateway. In particular, an FTP connection is set. Additionally, 5 CBR exchanges are incorporated into the simulations. They emit 4 packets/s and the packets have 512 Bytes. This inclusion introduces interferences so TCP-GAP can be evaluated in more realistic scenarios.

Mobile nodes are equipped with 802.11 compatible radio interfaces. The transmission range is set to 250 meters. The interference radius is 550 m and the propagation model used in the simulations is the Two-Ray Propagation model. Concerning the mobility of the nodes, they follow a Random WayPoint (RWP) mobility pattern. This is a well-known mobility model used in MANETs. Every mobile node randomly chooses a destination. Once selected, it goes to this point at a constant speed. The speed is also randomly computed from a minimum value to a maximum value. A uniform distribution function is assumed for this computation. Once the destination is reached, the mobile node stays in that position for a pause time. Then, it selects a new destination and it repeats the process. As recommended in [Yoon, J. et al, 2003], the minimum speed is set to 1 m/s. The mobility parameters and other simulation variables are listed in Table 1.

Table 1. Simulation parameters

Simulation Parameter	Value
Area	1000x1000 m²
Number of mobile node	50
Mobility Pattern	Random WayPoint Maximum Speed: [1, 5, 10] m/s Minimum Speed: 1 m/s Pause time: 0 s
Transmission range	250 m
Simulation Time	5000 s
Runs per simulation	40
Gateway Discovery	T : 5 s TTL : 3
Ad hoc routing protocol	AODV Local repair disabled Link Layer Detection enabled
MAC layer	802.11 b RTS/CTS enabled

Figure 1, 2 and 3 show the mean values obtained for the simulations for the three studied gateway discoveries. For each maximum speed, the tests were executed 40 times. The goodput represents the transmission rate perceived by the application layer. We differentiate between the uplink connection (from the mobile node to the Internet) and the downlink connection (from the Internet to the mobile node). In order to suppress the effects of the wired section, the host to which the data packets are sent is assumed to be directly connected to the Internet Gateway and an ideal connection with no losses is established between these two extremes.

In Figure 1, we have the results for the Reactive Gateway Discovery. In this case, the routes to and from the Gateway are discovered reactively so slight differences are perceived in the goodput of the uplink and the downlink connection. That means that the transmission rates at the mobile nodes and at the Gateway are set with similar values. The increment of the speed leads to more frequent route breakages so the goodput is reduced in highly dynamic scenarios.

On the other hand, Figure 2 shows the results when the Proactive Gateway discovery procedure is used. Under these circumstances, the routes from the mobile nodes to the Gateway are periodically updated so the perceived four-hop delay (FHD) is different in both senses. Due to this difference, the transmission rate is higher at the mobile nodes than at the Gateway. Thus, the goodput offered in the uplink connection is greater than in the downlink connection. Therefore, an asymmetrical performance is identified when the proactive gateway discovery is used.

Concerning the downlink connection, the proactive gateway discovery outperforms the reactive scheme. This is explained by the reduction of the solicitations that the Gateway must manage. This reduction represents a lower level of interferences and, in turn, an improvement in the TCP performance.

Finally, the hybrid gateway discovery (represented in Figure 3) turns into an intermediate performance. It outperforms the goodput offered by the reactive scheme but a symmetrical behavior is hold.

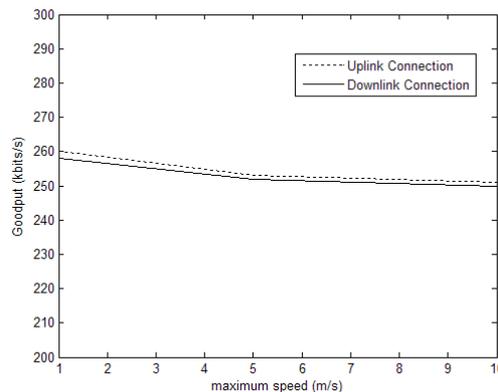


Figure 1. Goodput obtained in the reactive gateway discovery procedure.

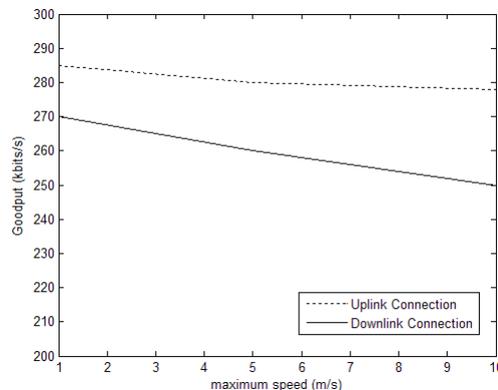


Figure 2. Goodput obtained in the proactive gateway discovery procedure.

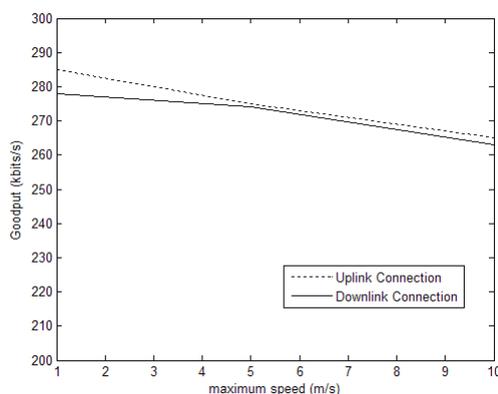


Figure 3. Goodput obtained in the hybrid gateway discovery procedure.

5. CONCLUSIONS

This paper analyzes the performance of TCP connections in Internet-connected MANETs. In particular, the TCP-GAP is used for the TCP communications. This protocol adapts its transmission rate to the congestion status of the network. The algorithm for the adjustment is different in the Gateway (which connects the MANET to the Internet) and in the mobile nodes. They are supported by the estimation of the four-hop propagation delay of the transmitted segments. Although this algorithm has already been studied in static scenarios, this delay is also affected by the time elapsed in the route discovery procedures. Therefore, a correct evaluation of the performance of TCP-GAP should comprise different gateway discovery procedures in mobile environments. This paper evaluates the impact of the gateway discovery and analyzes why this happens. We conclude that the gateway discovery procedure, which is in charge of updating the routes to the Gateway, represents an important effect on the goodput offered by TCP-GAP.

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