Cross layer metrics for improving transport protocols in multihop wireless networks

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RÉSUMÉ. *Notre travail s'inscrit dans l'amélioration des protocoles de transport dans les réseaux sans fil ad hoc multisauts. Nous présentons différentes métriques provenant des couches physiques ou liaison pour améliorer les performances de la phase de contrôle de congestion de TCP. Ce papier introduit une classification des métriques inter-couches pour améliorer le niveau transport.*

ABSTRACT. *Our work concentrates on improving the performance of transport protocols in multihop wireless networks. We present different metrics from link and physic layers to improve the performance of TCP congestion control. This paper introduces a classification of cross layer metrics used to improve the transport level.*

MOTS-CLÉS : *réseau sans fil multi-saut, métrique, classification, transport, routage.*

KEY WORDS: *multihop wireless network, metric, classification, transport, routing.*

1. Introduction

Wired and wireless (and multihop wireless) environments differ in many aspects since the medium loss rate, the shared nature of wireless channel, the throughput and the risk of disconnection between stations. Therefore, the use of the wired network predominant protocols, especially technology-independent ones of higher layers, faces challenges in keeping their performance in wireless networks. A well-known approach is to use cross layer information to better know the wireless environment and to adapt the response of the protocol. Improving routing function in multihop ad hoc network have been developed using metrics which are parameters of lower layers to characterize the wireless environment [PAR 09]. This approach did not pay much attention for Transport protocols.

In this paper, we focus on the definition of cross layer metrics used to improve the performance of transport protocols, not only TCP, working over multihop wireless links. Indeed, a transport protocol such as TCP or TCP-Friendly should use not only metrics of transport layer such as *Round Trip Time*, *Packet Loss Rate*, and *Throughput* but also, metrics of MAC and PHY layers such as *Transmission Rate*, *SNR* (Signal to Noise Ratio) and *BER* (Bit Error Rate) to gather more information about the wireless link. Thus, having more knowledge about the network can make the protocol efficiently adjusting its operation to improve performance in terms of throughput, delay or packet loss rate.

In this paper, we introduce and classify the current metrics at each layer and make a critical study of them, regarding their effectiveness and their availability.

2. Metrics of PHY Layer

The function of physical layer is to transmit raw bits over a certain distance with minimum bit errors, using a suitable power level. Thus the metrics of PHY layer can provide information about channel quality or signal strength.

For example, RSSI (Received Signal Strength Indication) is used as the measurement of the signal quality at the receiver side and is reported for each individual message, but it indicates only the strength of the signal at the receiver compared to a threshold [D16 04]. SNR is the ratio between the desired signal and its background noise while SINR (Signal to Interference plus Noise Ratio) takes also into account the interferences from other signals corrupting the desired signal. Using SINR will provide more accurate and reliable information about the channel signal compared to RSSI but with the cost of higher computation complexity and delay.

Using metrics of PHY layer directly for Network and Transport layers' protocols seems not to attract much attention since these metrics just provide "raw information" of signal strength level. These metrics, however, are most used to enhance the operation of the MAC layer. For example, information about channel quality can be used to adjust the modulation and coding scheme (MSC) or packet scheduling.

3. Metrics of MAC layer

The main functions of wireless MAC layer are improving link reliability, coordinating access to a shared radio channel to schedule the transmission of packet with minimum overhead and collision. This layer provides channel related information such as current FEC scheme, statistical information of transmission and medium access time. MAC metrics are concerned by the channel busyness around a node and the channel capacity.

Due to the contention access protocol, the channel access delay is defined by the time the MAC protocol [D11 07] spends to correctly transmit a packet over wireless link. The Contention Delay metric [HAM 08] is defined as a time interval from the time instant a frame is placed at the head of the buffer to the time instant the transmitter received correctly the acknowledgement of that frame. Both metrics depend on the traffic load over the link or the number of simultaneous transmitting stations. Other delays can be computed such as queuing delay or contention time. Another measurement of busyness is the number of retransmission attempts of a same frame.

[ZHA 07] defines the Channel Busyness Ratio (r_b) as the ratio of total busy periods of successful transmission or collision to the whole duration of observed time interval. [ZHA 07] measures the available bandwidth at each node from the value of r_b, thus the traffic source can adjust the amount of traffic injected to the channel ensuring that the network is fully utilized without severe congestion and contention. From r_b, Contention Delay metric and the frame size, the available bandwidth can be also derived as in [NAV 07].

At Transport layer, MAC metrics are used in conjunction with other metrics and schemes in order to improve the responsibilities of reliability, congestion control and flow control between end-to-end peers over the network.

4. Metrics of Network layer

The main functions of Network layer are host addressing, routing packets through networks, relaying between interfaces and QoS provision. Compared to the link metrics, network metrics will give information on the entire path instead of a single link. These metrics have been mainly developed to improve ad hoc routing protocol but some of them can be used to improve transport protocol and we introduce them.

For example, Draves et al. [DRA 04] define the Expected Transmission Time (ETT) of a link as the time for a successful transmission of a packet at that link and weight a path with the total of ETT of all links on that path. This metric can be submitted to the transport protocol so that it can assess the current available transmission rate of the network. Another metric, Interference-aware Resource Usage (IRU), was proposed in [YAN 05] to capture the effects of inter-flow interferences and the differences in the transmission rates and loss ratios of wireless links. The lower the IRU is, the better the link is in terms of making use of network capability. The transport protocol can use this metric to see whether the loss is caused by severe interferences on the transmission path.

5. Metrics of Transport layer

The Transport layer provides end-to-end communication services for applications over the network. As transport protocols have to operate on any network, they estimate the network state by using intrinsic metrics or events. The problem is that they are too coarse in some environments; the well-known example is the time-out event that is interpreted as congestion state and not as a transmission error. We introduce here the intrinsic metrics of Transport protocols that are based on throughput, reliability or delay measurements and cross-layer information.

Short-term Throughput (STT) is defined as the ratio of the number of packets successfully delivered to the total number of packets transmitted during an interval of T [FU 02]. The variation of the STT value allows the protocol to adjust the sending rate. However, using STT itself cannot differentiate between the congestion, network disconnections or bursty channel errors. For better decision, [HAM 08] proposes to take into account the value of Contention Delay and to react in consequence.

Packet Loss Ratio (PLR) [FU 02] is the ratio between missing packets and the total sent packets in a time interval T. When the PLR value is suddenly high, the transport protocol has to choose between congestion, route change and channel error to perform appropriate actions. To come to a more precise decision, the MAC metrics should be used in extra. For example, if the channel busyness ratio r_b (section 3) is above its threshold, which means that there is severe contention (high load) somewhere on the path, then the loss caused by congestion has a higher probability and the traffic source should reduce its sending rate.

Z.Fu et al. [FU 02] define Inter-Packet Delay Difference (IDD) as the difference between the travel time (from the time the packet was sent to the time it is received) of consecutive packets. If the value of IDD increases apparently, it is a high probability that the network enters congestion or route change state since the effect of random channel errors and packet sending behaviors to IDD is negligible. The other two options can be solved out by consulting lower layers' information.

6. Conclusion

With the mature of wireless technologies, with or without infrastructure, and the ever-rising need of multimedia over wireless, many multimedia-supported transport protocols are used to meet the demand of the customers such as TFRC, RTP, DCCP or SCTP. To overshoot the problems caused by wireless environment and multihop path, there is a need of enhancement for the transport protocols to work correctly in wireless networks. Transport metrics combined with cross layer informations provide an effective and flexible method to solve this problem.

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