Enhancements of WLAN MAC performance

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I. INTRODUCTION

The real potential of broadband wireless networks lies on the mobility, the success of Wi-Fi network with IEEE 802.11x technology makes it possible to access broadband with low cost. Numerous research work have focused on several issues inherited from the wireless technology such as security, reliability, transmission rate, etc. However, if we take a closer look at the core feature of 802.11, the contention based CSMA/CA access method, three intrinsic problems can be still identified: 1) Performance degradation due to the lack of flow control between the MAC and upper layer resulting in potential MAC buffer overflow; 2) Unfair bandwidth share issues; 3) 802.11 Performance Anomaly. In this paper, based on the 802.11 MAC layer analytical model, we give a brief description on our cross layer based solutions to the mentioned problems. The preliminary results from the simulation and experiments have demonstrated the feasibility of our proposals. Real deployment is planned in our future work.

II. 802.11 MAC LAYER MODELING WORK

We established an analytical model [2] which allows accurately estimating the available bandwidth delivered by WLAN MAC layer according to several parameters that can be easily monitored by the access point. The proposed model pushes further the approach proposed in [1] by considering both the mobile nodes' transmission rate status and the bandwidth use profile of the different flows. Such an analytical model can be integrated in the end systems or wireless routers to estimate the maximum bandwidth supported by WLAN MAC layer of each mobile node in scenarios where different protocols are involved (i.e. TCP, UDP, TFRC, etc.). Our analytical model has been validated by a set of simulations under OPNET.

III. ISSUE OF WLAN MAC LAYER OVERFLOW

In the context of 802.11, the high layer of the mobile node is unaware of the MAC layer information (i.e. the maximum bandwidth supported by WLAN MAC layer) due to the systematic absence of flow control between the 802.11MAC layer and the upper layers. The rate at the transport layer can strongly diverge from the rate offered by the 802.11 MAC layer, and results in numerous losses at the WLAN MAC buffer, therefore degrades the quality of transmission. The principal of our solution is to make the higher layer aware of the MAC layer maximum supported rate. Based on our modeling work, we propose a cross layer rate control

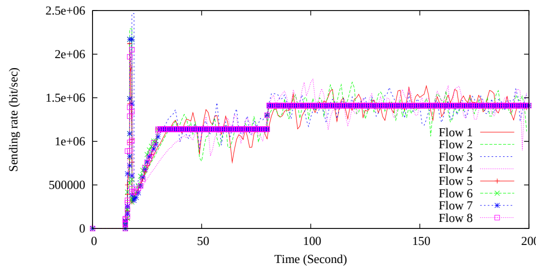
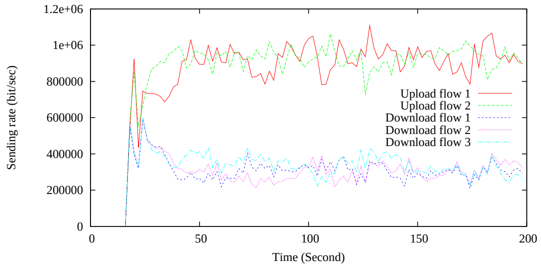


Fig. 1. TFRC sending rate with and without rate-adaptation mechanism

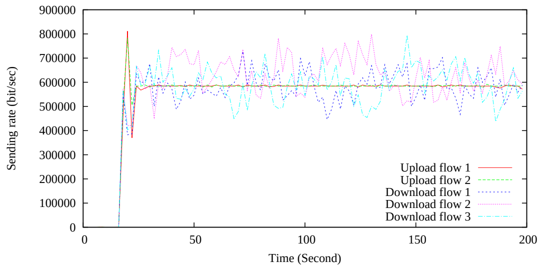
mechanism, which efficiently adapts the sending rate of the transport layer to the MAC layer available rate. This approach can induce a specialization of TFRC (TCP Friendly Rate Control, RFC 3448) where every mobile node compares its processed TFRC equation based sending rate (X_tfrc) with the maximum available throughput supported by the MAC layer (Xm). If the calculated X_tfrc is higher than Xm, the sending rate is then adjusted to Xm to avoid congestion and losses at the MAC layer. In our simulation work, we suppose four TFRC mobile nodes are transmitting real-time data to the remote server via the current access point, two of the mobile nodes keep using a transmission rate of 11Mbps. The other two mobile nodes use the transmission rate of 5.5Mbps between t = [15sec, 80sec] and 11Mbps from t = 80sec. Fig.1 represents the sending rates of default TFRC (flow1-4) and rate adaptation based flows (flow5-8). The unstable and oscillated rates (flow1-4) are due to the overflow at the MAC layer, we observe that a number of packets are dropped by the MAC layer for the default TFRC flows while none packets are dropped for the flows based on our rate adaptation mechanism.

IV. ISSUE OF FAIRNESS DEGRADATION

Fairness degradation is one of the most challenging issues in the context of 802.11. We address two main unfairness problems in this section: 1) Unfairness issue between UpLink (UL) and DownLink (DL) flows. Since the access point (AP) is considered as a normal contention-based mobile node, it has the same opportunity of sending packets (to all the download mobile nodes) as any of the upload mobile node, so the UL mobile nodes occupy much more bandwidth than that occupied by the DL nodes. 2) Unfairness issue between ACK clocked (i.e. TCP) and Non-ACK clocked (i.e. UDP) flows. When ACK and Non-ACK clocked UL flows coexist, the contention avoidance procedures implemented in the 802.11 MAC layer



(a) Sending rate in default case



(b) Sending rate with rate-equalization mechanism

Fig. 2. TFRC rate with and without rate-equalization mechanism

of AP can slower the rate of returned ACK packets to the UL mobile nodes in the coverage of AP, and as a result slower the sending rates of the ACK clocked flows. Different from the traditional solutions that requires modification to the 802.11 standard, our proposed rate equalization mechanism situated on higher layer allows constraining the sending rates of the upload mobile nodes and the Non-ACK clocked connections to an estimated rate based on the 802.11 MAC analytical model. As a consequence, our approach allows the AP to gain more sending opportunities for the DL connections and for the transmission of the returned ACK packets. The throughput of DL and ACK clocked connections are then increased and fairness is dramatically improved. In the illustrated scenario, we show one of our simulation work that focuses on the fairness between TFRC UL and DL flows, we consider that two mobile nodes upload TFRC flows (of which the transmission rates are respectively 11Mbps and 2 Mbps) and three mobile nodes download TFRC flows with transmission rate of 5.5 Mbps. Fig.2 shows the sending rate of each TFRC flow in default and rate equalization based cases. The simulation results show that the fairness issue is significantly improved.

V. ISSUE OF 802.11 PERFORMANCE ANOMALY

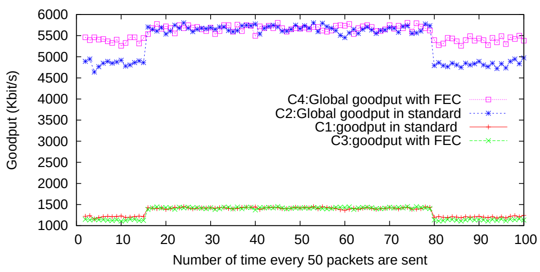


Fig. 3. Global and individual goodput

The 802.11 performance anomaly was firstly raised in [1], it was proved that mobile node with the lowest transmission rate impacts on the performance of every mobile node in the coverage of the same AP. The 802.11 access method which guarantees the equal sending opportunity for each mobile node and results in a round robin discipline in steady state for media access is the origin of such syndrome. The UL bandwidth for each mobile node in the same AP coverage is proved to be identical and strongly depends on the number of competing hosts and their respective transmission rates. In the context of 802.11, Auto Rate Fallback (ARF) has been largely implemented in the current 802.11 products. Consecutive packet losses, after applying some degree of ARQ (Automatic Repeat reQuest) persistence, are then considered to downgrade the current modulation rate in order to guarantee the quality of the transmission, and therefore aggravate the 802.11 performance anomaly. We have demonstrated that cross layer cooperation between an adaptive upper layer FEC based mechanism and the ARF mechanism can alleviate this performance anomaly and improve the overall goodput. Our approach aims at, even when the channel condition degrades, trying to maintain the current higher modulation rate while keeping the transmission reliability in the current communication context. This is done by applying to the considered connection an adaptive FEC mechanism of which the expansion ratio is estimated according to the monitored Packet Error Rate (PER). Such approach allows delaying the modulation downgrade and occurrence of the performance anomaly syndrome, and therefore results in a higher global goodput. In our first experimental test, we assume that three mobile nodes are always in the high level communication conditions (11Mbps). The fourth mobile node is initially in poor channel conditions (transmission rate of 5.5Mbps in default case) and then moves towards the good signal coverage zone for around 65 seconds and returns to its initial point. With our high layer FEC based mechanism, the mobile node is forced to use a high transmission rate of 11Mbps even in the degraded signal coverage while applying FEC redundancy packets at the IP layer. Fig.3 shows the measurements of the global goodput and individual goodput of the fourth mobile node. Compared to the default case, we can observe a significant gain (1.12) of the global goodput.

VI. CONCLUSION

This paper addressed three issues in the context of 802.11, which are important but somewhat ignored in the current research. We then give a brief description of our cross layer based solutions which entails no change in the 802.11 standard. The preliminary measurements show a significant improvement on the wireless transmission efficiency, our future work will focus on the real deployment while taking into consideration the optimality criteria.

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