Development and Experiment with Scheduling and Network Coding tools in Wireless Testbed

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Abstract

In 802.11 wireless networks, when nodes are connected to wireless LAN, nodes are connected to an access point; therefore, nodes compete with each other for gaining access to the wireless medium. The competition causes error, contention problem, and thus there is problem with throughput that users could experience. In order to improve the performance throughput, logically, it might be good that the wireless medium is given priority to the long-delay-sensitive flow where sized-based scheduling, which it gives priority to the short flow, is adopted between users. Network Coding (NC) could also increase the bandwidth where the intermediate nodes are able to combine the packets coming from different flows, using Linear Network Coding, into one or several packets.

The goal of this paper is seeking for better performance throughput, where the experiment are implemented with both sized-based scheduling and NC techniques in a wireless testbed. The sized-based scheduling is implemented and compared to the standard scheduling applied on access point side. NC is implemented in both access point side and station side. Both techniques are implemented with Click Modular Router tool.

Keywords: Sized-based scheduling, Least Attained Service (LAS), Network Coding, Click

1 Introduction

In 802.11 wireless networks, when users connected to wireless LAN, users are connected to the same access point; therefore, users compete with each other to gain access to the wireless medium and losers might wait for a long period of time to gain access to the wireless medium; and so called contention problem. In wireless transmission, we also have problems of noise during the transmission.

To improve the performance and deal with the contention problem, one can use solution of scheduling. Scheduling is able to consider which users or which flow could access the medium. In addition to scheduling we also have Network Coding (NC). NC is in general used at intermediate nodes on the path between source and destination. Those intermediate nodes mix packets using linear network coding. Alternatively, we can use NC at a single location, the access point in our case, to combine several packets of several flows together. NC is also used at destination for decoding the combined packets in to original packets.

For better performance throughput, both techniques of Scheduling and Network Coding are studying in this paper. The objective of this paper is to implement both network coding and sized-based scheduling in a wireless testbed with Click Modular Router tool running on Linux fedora system.

2 Related Work

We begin with a summary of prior work on sized-based scheduling and network coding.

2.1 Sized-based Scheduling

In the network best effort model, all flows are transmitted without priority in term of flow size. On the contrary, network throughput as well as RTT could be improved by paying special attention to size of flows. Rai, Biersack, and Urb-voy-Keller [1] and Biersack, Schroeder, and Urbvoy-Keller [5] have studied sized-based scheduling policies which give priority to the short flows.

A typical example is Least Attained Service (LAS) where the next packet to be served is the
one that belong to the flow which received the least amount of service. LAS is also a buffer management mechanism. When the queue is full (unlike droptail) it inserts the appropriate packet in the queue and then drops the packet at the end of the queue. LAS intended to be deployed at the network edges where congestion can take place.

**Implementation**

\[ S_f = S_f + P \]

Where f is flow, \( S_f \) is accumulative value of service served for the flow, and P is packet size. The lower the value of \( S_f \), the higher the priority is.

The implementation with LAS scheduling gains advantages such as lower RTT during Slow Start phase and decrease of short flow losses. LAS also improves the mean response time since most TCP flows are short, while more than 50% of the bytes are carried by less than 5% of the largest flows for typical internet [1].

**2.2 Network Coding**

As mentioned above, in the 802.11 wireless network, when the AP transmits frames to one specific station in unicast mode, even though the other stations overhear the frames, they drop those frames since the MAC address did not belong to them. When NC is used, this behavior will be modified, so that stations store those frames for future use, even though the MAC address does not belong to the stations.

NC mechanism allows the intermediate nodes to combine several input packets into one or several output packets by using linear network coding. Some research papers such as XORs in the Air [6], and XOR Rescue [7], demonstrate the advantage of NC for gaining advantages in term of bandwidth and mean response times.

To improve the performance of network transmission, the COPE mechanism [6], which it uses network coding technique, can be used. The idea is described in figure 1 that after the router received frames from A and B, the router spends only one time slot for transmitting frames a and b to both stations. So, COPE spends only 3 times slots for the transmission.

With NC [8] that is used in COPE, after the access point received all frames, a and b, with different destinations, it encodes the incoming frames into one encoded frame, a+b, then it sends out to the stations with the destination address of station A, for example. At the stations side, the promiscuous mode is set; thus, each station is able to receive the frames even though the destination address of the frames does not correspond to the stations. To get back the native frames from the encoded frames, the stations need to decode the encoded frame with the other native frames which are stored in their buffer pool and do not belong to the stations.

**2.3 XOR Rescue**

XOR Rescue (XORR) [7] is a NC-aided retransmission scheme which could improve the performance of the network transmission in term of bandwidth, expected goodput, and service time. XORR also keep overheard frames for future use as well.

**Sender (AP) side**

At sender side of XORR, AP has a queue for each station. For preventing queue reordering, only HOL from each queue could be the candidate for scheduling selection for doing the transmission. The queues are splitted into two groups, the Transmission queue (TxGroup) and Retransmission queue (RxQueue).

AP transmits frames to stations; and if the transmission to some stations fails, AP freezes the queues to those stations and places them to RxGroup. For the queues that have successfully received frames by the stations, AP still continues transmitting the frames until:

- The freeze time reaches the threshold t
- The Number of frozen queues reaches its threshold thr

Then, after t or thr is reached, the AP will do the retransmission from queues inRxGroup. If there are two or more frames to be retransmitted, the AP will do NC on some frames among the
frames to be retransmitted based on its coding metric. The XORed frames are called coded frames and the un-XORed frames are called native frames.

**Receiver (station) side**
The characteristic of XORR at receiver side is that when the receiver hears the native frames which belongs to it, the receiver transmits an acknowledgment (ACK) to the AP. If the receiver overhears the native frames that is not destined to it, those frames are stored in its native frame pool.

When the receiver hears or overhears the encoded frames, the receiver tries to decode the encoded frames immediately. The receiver can successfully decode the encoded frames only if it has other native frames in the native frame pool. After successfully decoding and if that native frames belong to the receiver itself, it will transmit the ACK to AP for removing the frames from queue at AP; however, if that native frames do not belong to the receiver, it will store the frames to its native frame pool. In contrast, if the receiver does not successfully decode the encoding frames, those frames are discarded.

### 2.4 Synergy between XOR Rescue and Sized-based Scheduling

The XOR Rescue mechanism, as described above, improves the network performance in the context of packet based opportunistic scheduling. Sized-based scheduling also improves the throughput of the transmission in the context of flow base scheduling. Thus, the goal of this project is to combine both techniques for better performance throughput. For the current time as a first step of this paper, the set up of a wireless testbed is made with such kind of transmission scheme.

The experiment is made on a wireless testbed as shown in figure 2 where a PC acts as the AP and the other two PCs are run as stations. Assume that all devices, AP and stations, can hear each other well which mean that there is no hidden node problem; and the communication takes place only between AP and Stations.

With XORR mechanism and during the retransmission phase, the AP selects the frames to be encoded for maximizing the performance based on channel conditions. However, we decided not to implement this mechanism. Instead, the encoding operation is made with all retransmitted frames simultaneously when retransmission is triggered. The number of station is fixed. In our testbed, there are two stations.

### 3 Implementation

#### Sender Side
AP is installed with click where the flow chart of implementation is described in Figure 3. The configuration at AP is using XORR mechanism. In XORR mechanism, the click router receives frames from network interface cards eth0. Next, the AP implements encoding operation with LAS scheduling and then forwards frames to Wireless interface, wlan0.

#### Receiver Side
The station received encoded frames from AP, then the station do decoding operation to get back the native frames and after that it forwards the frames to upper layer and replies the ACK to AP. Figure 4is the receiver flow chart of XORR at the receiver (stations) side. The click router communicates with AP with wireless interface, wlan0.

### 4 Experimental Result

The performance of the network is studied and analyzed in this chapter since network performance is the very important point for users’ requirement. Even though the theory shows that the new technologies are better than the old one, it is the main criteria of having the practical performance in order to support that new theory of the new technology.

Figure 5, 6, and 7 are performance comparison on TCP transaction between FIFO and LAS
Figure 3. Flow chart of our implementation of sender (AP) side.

Figure 4. Flow chart of our implementation of receiver (AP) side.

Figure 5 and Figure 6 describe real-time performance of Networking using FIFO and LAS in bits and in packets respectively. From the graphs, LAS scheduling is more stable than FIFO scheduling; as in Figure 5 (a) from 0s to 45s, the traffic of FIFO is vary from almost 0 bit to 550000 bits and the traffic of LAS in Figure 5 (b) is slow at the start, but after 15s the traffic is stable with rate of around 520000 bits. The graphs in Figure 6, describing the performance in packets, also have the same network performance as in bits in Figure 5.

Figure 7 shows the differences between retransmission rates of FIFO scheduling and LAS scheduling in real-time performance. From the graph, the rate has range from 0 frames to 9 frames with retransmission rate of LAS a little higher than FIFO.

Even though the retransmission rate of LAS is higher than FIFO, but the difference is not much if compare to the rate of frames transmitted with real-time in figure 6. Therefore, in conclusion using LAS scheduling instead of FIFO scheduling implemented in an access point, users could have better network performance experience.

5 Conclusion

The two techniques of sized-based scheduling and network coding run on click tool and
using C++ language to build new elements could produce outcomes which the experiment could:
- Be implemented sized-based scheduling (LAS), FIFO scheduling and network coding (NC) on Click Modular Router tool.
- Obtain network analysis of sized-based scheduling (LAS) and FIFO scheduling.
- Obtain better performance throughput by implementing sized-based scheduling (LAS) compared to FIFO scheduling when they are implemented on an access point.
- Successfully transmitted and received by using Click Modular Router tool with NC implementation; and therefore, the better the transmission throughput after NC completion configuration.

For the full experiment of XORRR for the project with performance analysis would be the future work.

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References