

Managing Wireless IPTV in Multimedia Home Networking

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Abstract— In-home wireless networks are now wide-spreading as today's home network is composed of at least one wireless network. The dramatic increase of traffic makes it difficult to guarantee user experience. In this paper, we focus on wireless IPTV service that needs to be guaranteed by service provider. It is particularly complicated to manage because of the shared and unstable condition of the wireless medium. Moreover, with stringent requirements at application layer, using UDP at transport layer and traditional MAC protocol at link layer can hardly result in satisfaction at users. Therefore, we investigate comparison of different combinations of transport and link layer performances for the delivery of IPTV. For validation, we use NS-3 and a realistic propagation generated with a real house description. We analyze impact of link layer (with or without coordination) and transport layer (UDP or TCP). Then, we propose a combined solution using TCP over a coordinated MAC protocol. The solution can be easily deployed in real products and is compatible with existing devices.

Keywords— IPTV, Multimedia Streaming, Wireless Networks, Home Network, TCP, UDP

I. INTRODUCTION

Tremendous increase of streaming applications has been observed currently and this trend will continue rising in the near future. With an emergence of wireless devices (e.g. tablets, smartphones...), streaming over wireless medium becomes common. In consequence, wireless resources need to be managed wisely in order to satisfy all users who share the same network. Since the nature of wireless medium is a share and open environment, it is prone to all types of interference and disturbance thus very difficult to control. This paper will focus on the in-home wireless network that is now wide-spreading as every home network consists of at least one wireless network today. We observe two factors that are limiting the quality of video delivery in home network. First, heterogeneity of houses with difficult propagation conditions induces transmission errors. Second, dense urban areas bring interference from neighborhood environments, therefore collision between transmitters. According to the standard IEEE 802.11 [1], a set of transmission rates is available for adapting to network condition. For instance, there are eight modulations in IEEE 802.11a [2], the higher the modulation the higher the throughput. However, it is hard to achieve high

throughput everywhere in the house with only single access point (AP). As a result, multiple-AP approach [3] has been proposed to overcome this coverage problem. For interference from neighborhood, we assume here that one channel is assigned per house as there are several channels (19) available in 5GHz band. Appropriate channel allocation mechanism is used to attribute channel to each house. When multiple operators are presented in the same area, they share the resource and manage their own channels as desire.

For the network application, we will focus on video streaming applications. The dramatic increase of network traffic makes it complicated for service provider to guarantee user experience of these services. We distinguish two types of video services in home networks: *Over-The-Top (OTT)* video applications such as HTTP streaming (YouTube) that are not guaranteed by network operator; and *IPTV application* with very stringent requirement that are guaranteed by network operator according to a specific SLA contracted to its customers. The requirement that is difficult to achieve for IPTV service in wireless home network is the packet loss rate (PLR). According to the specifications [4], only one packet loss is tolerated during a film or duration of one hour. We will focus on this second type of application. To overcome the problems, our idea is to use TCP for streaming application such as IPTV in home network so we try to answer the following questions:

- *Question 1:* Is there an opportunity for wireless IPTV over TCP in home networks?
- *Question 2:* What are the advantages and drawbacks of wireless IPTV over TCP?
- *Question 3:* Does TCP overtake the link layer enhancements required for Wireless IPTV?

In this paper, we illustrate preliminary results of comparison between UDP and TCP transmission of IPTV service in home network. We also integrate multiple-AP architecture for comparison of performance of repetition at the transport layer versus collision avoidance at the link layer. More precisely, we investigate IPTV service performances with enhancements at two fronts: link layer and transport layer. At the link layer, two approaches have been studied; one is coordinated transmission and the other is distributed transmission. Both of them deploy multiple access points in

order to accommodate a good coverage (with high modulation) everywhere in the house. At transport layer, we compare performances using TCP versus traditional UDP upon the previously described link-layer approaches. The processing power of chipsets embedded in new generation gateway and media server now enables conversion of UDP streams coming from outside networks into TCP streams transmitting in the home network. In fact, the transport protocol conversion from UDP to TCP can be performed, for example, by a central gateway, which is already present in every home network today.

Therefore, our contributions concern an investigation of transport and link layer performances for the delivery of IPTV service. We use NS3 for the evaluation. To have realistic simulation, we feed NS3 with realistic propagation generated using a ray-tracing tool with a real house description. The obtained results demonstrate advantages of using TCP with coordinated access to guarantee higher number of IPTV sessions comparing to UDP. This combined solution can be deployed easily in real products and they are compatible with existing devices.

The rest of this paper is organized as follow. Section II provides backgrounds on video streaming in home networks. Section III describes the proposed scheme. Section IV presents performance evaluation. Finally, Section V draws conclusions and future works.

II. IN-HOME VIDEO STREAMING

In this section, we briefly provide backgrounds on video streaming, especially IPTV, in home networks today along with different options that can be deployed for its transmission.

A. IPTV in home networks

It can be noticed that IPTV service has strict requirements on several parameters. First, since it is a real-time transmission, the latency should be less than a few hundreds milliseconds [5]. It also requires high throughput as video encoding rate increases and we can see SD and HD flows in home networks today. Last but not least, IPTV is a quasi-error free transmission; the loss rate tolerated by this application is extremely low ($PLR < 10^{-7}$).

Access networks delivering IPTV to the home gateway uses MPEG/UDP streaming (either multicast for live or unicast for VoD) over xDSL technologies. Broadcast networks also use MPEG streaming (broadcast) over Terrestrial (DVB-T), Cable (DVB-C) or Satellite (DVB-S) technologies for delivering TV to the home. In the home network regarding link layer, we can have wired medium (Ethernet, Powerline, MoCA,...) or wireless medium (IEEE 802.11,...). However, due to home diversity and unreliable propagation conditions of the wireless medium, managing wireless IPTV service becomes very challenging. This is why we choose to investigate this type of network in this paper.

B. Transmission options

In wireless communications, transmission errors are due to propagation (i.e. low SNR) or collision (i.e. interference,

hidden node...). In both cases, the PLR can be reduced with retransmission of the data at either transport layer or link layer. For the latter case, collision avoidance mechanism is also an alternative. We briefly explain different options here.

At the *transport layer*, live video streaming uses traditional UDP but since UDP is unreliable, TCP has become an alternative as contrary to UDP, it implements retransmission and congestion avoidance mechanisms [6].

At the *link layer*, single-AP infrastructure is deployed by default in home network. In order to enhance the link budget, multiple-APs infrastructure has been deployed, either with a simply "Distributed" AP (better SNR) or "Coordinated" AP (collision avoidance) [7].

Moreover, to privilege IPTV traffic, one can make use of WMM [8] and IEEE 802.11e [9]. We recall their concept here. WMM provides priority access for different traffic categories, i.e. traffic having low priority will have less chance to access the medium than traffic having high priority. This can be done via configuration of contention window such as CW_{min} and CW_{max} (resulting in different backoff values) as presented in TABLE 1. Consequently, WMM can bring some QoS (i.e. DiffServ) for different traffic categories like between OTT HTTP streaming and IPTV.

TABLE 1. DEFAULT WMM PARAMETER SET

AC	CW_{min}	CW_{max}	AIFSN
AC_BK	a CW_{min}	a CW_{max}	7
AC_BE	a CW_{min}	a CW_{max}	3
AC_VI	(a $CW_{min}+1$)/2-1	a CW_{min}	2
AC_VO	(a $CW_{min}+1$)/4-1	(a $CW_{min}+1$)/2-1	2

III. PROPOSED SOLUTION

In this section, we describe the methodology of our proposed solution. We deploy different concepts that can be summarized in the following.

- **Multiple-APs architecture**

As shown in recent studies [10], a single AP cannot provide sufficient throughput for IPTV service with almost full house coverage. As a result, we need to deploy multiple APs in the home; these APs are connected to the gateway (GW) through a wired link (e.g. Ethernet, Powerline, MoCA).

- **Coordinated-APs**

In order to guarantee the PLR requirement of IPTV service, coordination among wireless transmissions can be achieved at the link layer as presented in [3][7]. This first approach improves collision avoidance mechanism at the link layer.

- **TCP for video streaming over Wi-Fi**

The second approach is to add retransmission of packet at the transport layer (via TCP) when the link layer did not successfully transmit a packet. Study in our laboratory has demonstrated that the conversion of incoming UDP traffic to TCP traffic can be achieved internally by the home gateway.

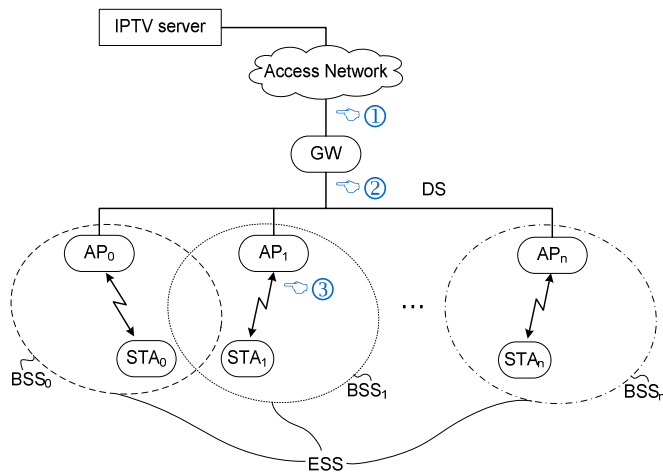


Figure 1. Network overview

The network components in consideration are depicted in Figure 1. Several access points (AP) are deployed in the house in order to achieve almost full-house coverage at a satisfactory throughput. The IPTV streams are transmitted from the IPTV server through the access network and received by the gateway (GW) – encapsulated in MPEG/UDP format (①). The GW then transmits streams to the home network (②) – encapsulation can be converted to MPEG/TCP for retransmission at the transport layer. Finally streams are transmitted over Wi-Fi (③) – coordination among APs can be enabled to avoid collisions.

IV. PERFORMANCE EVALUATION

In this section, we provide a case study within a real house configuration. The principal scenario concerns downlink-only streams, which represent different IPTV flows (for example, TVs or tablets in multiple rooms). The second scenario concerns mixed downlink-uplink streams with additional uplink streams that represent OTT videos (for example, recorded movies on DLNA servers, etc.). The study will compare the performance of IPTV service delivery using different combinations of :

- UDP or TCP transport protocol for IPTV service
- Distributed or Coordinated link layer

A. Test Set up

We describe here the test setup concerning network topology, test scenario, and configurations of NS-3.

1) Topology

Our topology consists of a house with two floors equipped with a set of access points {2, 4, and 8}. We investigate this multiple-AP infrastructure of in-home wireless network while number of access points in the home infrastructure can increase until 8 access points (equivalent to one AP per room in a standard French house size [11]).

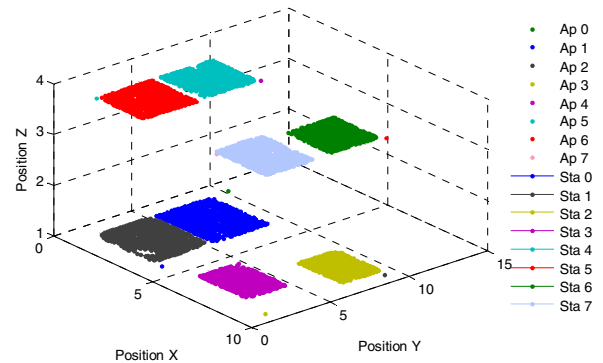


Figure 2. APs positions and Nodes' mobility

2) Scenario

In the principal scenario, there are eight downlink IPTV transmissions of 4 Mbps, which represent SDTV service with MPEG-4 AVC codec, one in each room. In the second scenario (mixed scenario), video flows in the downlink direction represent four IPTV streams of 4 Mbps each. Video flows in the uplink direction represent four OTT streams of 4 Mbps each, which represent recorded movies available in the home networks. Therefore, two types of access classes are identified using WMM : high quality video (IPTV) and best effort video (OTT).

3) NS-3 configuration:

We use NS-3 [12] for its capability of generating PCAP files that are used in our post-processing step (via Matlab). We use the realistic propagation generated from a ray tracing tool (Volcano [13]) and a real house description. We configure the NS-3 parameters as presented in TABLE 2 and TABLE 3. As previously described, the WMM is enabled in order to give privilege to IPTV traffic (in mixed scenario). Moreover, when TCP is in use, we deploy *NewReno* [14] without selective ACK. Note here that we use the default TCP parameters (outstanding window size, congestion window, RTT, slow start threshold); ones can adapt these parameters as desired. We leave them flexible in our proposition.

TABLE 2. NS-3 Wi-Fi CONFIGURATION

Parameter	Value
Standard	IEEE 802.11a
Frequency channel	5GHz, 20MHz BW
Noise figure	7+19 dB
ED/CCA threshold	-82/-62 dBm
Output power	15dBm
Tx and Rx antenna gains	2dBi
Rate control algorithm	Ideal
WMM QoS	Enabled

TABLE 3. NS-3 TCP CONFIGURATION

Parameter	Value
Congestion control	NewReno
Maximum Segment Size	1316 Bytes
Selective ACK	No

B. Results

We discuss results here in different aspects. We start studying TCP with and without coordination at link layer. Then we continue with a comparison between TCP and UDP with coordination at link layer. After that we discuss the delay issue, which is crucial in video streaming application. Last, we analyze the impact of OTT traffic.

1) TCP in multiple-AP infrastructure (with vs. without coordination)

Figure 3 depicts performance comparison in terms of PLR and number of successful flows when using TCP at transport layer and using distributed (D) or coordinated (C) approaches at link layer. It can be seen that using combination of TCP at transport layer and coordination at link layer provides better performances both in terms of PLR and the number of successful flows (i.e. flow that has $PLR < 10^{-7}$). This can be explained with the fact that coordination among APs reduces drastically collisions, retransmissions, hence losses and the number of successful flows. Note here that packet losses in TCP are those that arrived too late for the display. In our test, we set this delay to 200 milliseconds. As for different numbers of APs, we can notice that using more APs can be beneficial especially when they coordinate their transmission. It can be remarked here that the cost of increasing APs in home is insignificant as AP's price decreases.

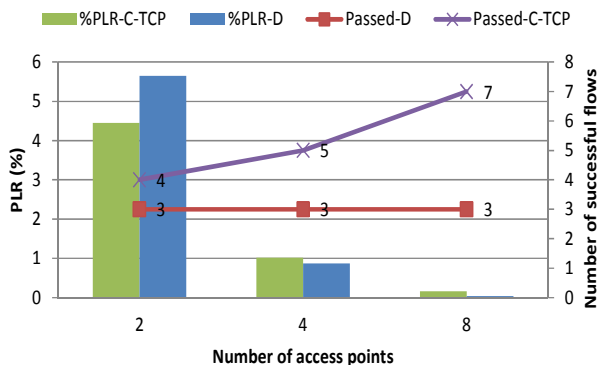


Figure 3. TCP: distributed vs. coordinated APs

2) UDP vs. TCP in multiple-AP architecture with coordination

Figure 4 depicts comparison between using UDP and TCP at transport layer while using coordination at link layer. It can be noticed that performance of TCP outperforms that of UDP significantly. In fact, we can observe high loss rate with UDP when deploying 2 and 4 APs comparing to almost 0 loss with

TCP. Finally, the number of successful flows results from these losses leading to the same conclusion.

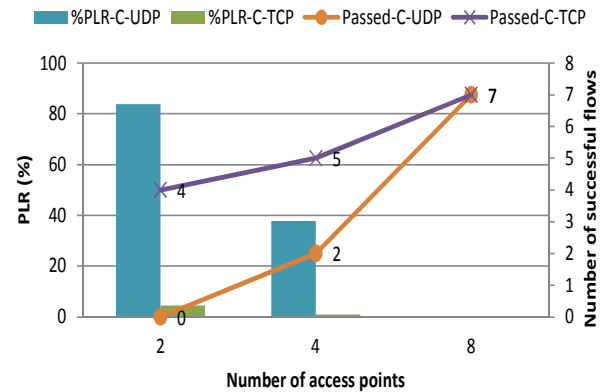


Figure 4. UDP vs. TCP in multiple-AP architecture (with coordination)

3) Latency

It should be mentioned that the latency issue is crucial in TCP as retransmission at transport layer may affect greatly this parameter and make TCP useless for transmission of real-time stream. Figure 5 depicts this metric comparing between using TCP with and without coordination at link layer. Latency in our case is defined as the difference between the timestamp of packet sent by the access point (T_{sent}) and the one of packet received at client (T_{recv}). It can be noticed that UDP performs obviously better than TCP for latency as there is no retransmission of packets like in TCP. However, if we look at the value of latency in all cases using TCP, none of them exceeds the general requirement of 200 milliseconds for video streaming application [5]; so the QoS can be preserved. Buffering mechanism then can easily absorb this latency.

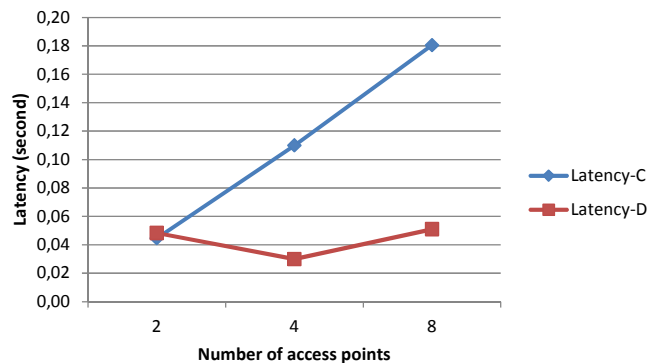


Figure 5. TCP latency with and without coordinations

4) UDP vs. TCP in mixed scenario

In this scenario, we added OTT traffic in order to observe its impact. For that WMM is enabled to distinguish between different access classes; AC_VI for IPTV transmission and AC_BE for OTT video (i.e. best effort traffic). Figure 6 depicts the performance in terms of goodput and number of successful IPTV flows. It can be noticed that using WMM, IPTV flows have better QoS than OTT video flows in all

configurations. The goodput is guaranteed in the case of UDP; and three out of the four IPTV streams passed PLR and latency requirements with coordination enabled (UDP-C case), which provides the best result. As for the case of TCP, results are almost the same with or without coordination regarding IPTV requirement. We investigated deeper and found out that with this mixed scenario, the maximum reachable throughput [15] is saturated; that is why the TCP performs worse than UDP.

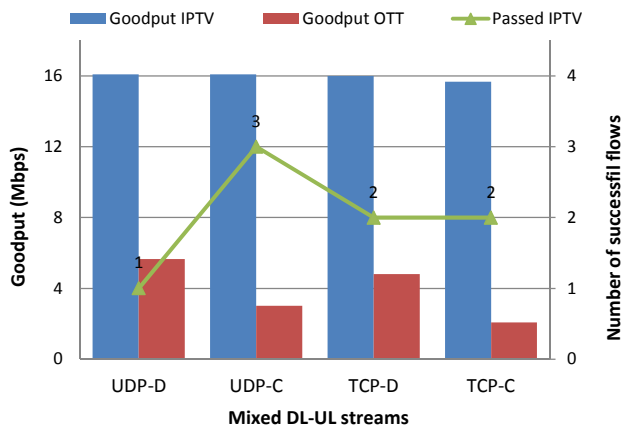


Figure 6. Mixed: distributed vs. coordinated APs

V. CONCLUSION AND FUTURE WORKS

We have proposed a combined solution, which uses TCP at transport protocol and coordination at link layer, for IPTV transmission in home network environment. This proposition is feasible as now processing power of home gateway enables conversion of UDP streams to TCP stream. Moreover, it can be implemented easily in real products and is compatible with existing devices. The obtained results demonstrate better performance than using UDP, in the normal condition. However, when the ongoing traffic exceeds the maximum reachable throughput of the network, TCP can no longer guarantee the requirement in terms of delay; and hence the impact of the loss packet begins to appear (loss due to late arrival for the display).

As a conclusion, we recommend to use both TCP at transport layer and coordination at link layer when possible. This combination guarantees IPTV requirement and obtain the best performance except when network resource is saturated. In the future, we aim to investigate more in details saturated scenario and to measure quality of experience (QoE) of users.

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