Performance Analysis of WiMedia UWB MAC

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Abstract—Ultra Wide Band (UWB) technologies have attracted a lot of attention recently due to their large bandwidth and low emission, which are suitable for in-door, high-speed multimedia communications. In this paper, we focus on the modeling and analysis of WiMedia UWB Media Access Control (MAC) protocols, particularly Prioritized Channel Access (PCA) with the presence of Distributed Reservation Protocol (DRP). Such analysis is for the first time evaluated in a commonly-used network simulator (NS-2). The performance results show the effectiveness of the improved models, and indicate the further enhancement for UWB-based IPTV in-home distribution networks.

Index Terms—UWB, MAC, modeling, analysis and evaluation

I. INTRODUCTION

The miniaturization of portable, electronic devices and the desire for always-available, multimedia services have driven the proliferation of Wireless Local Area Networks (WLANs) and Wireless Personal Area Networks (WPANs) due to their flexibility and increasing affordability. For example, many service providers, enterprises, consumers and even municipalities have installed IEEE 802.11-based WLANs to cover highly-populated areas, and Internet Protocol Television (IPTV) service providers nowadays are looking at various WPAN technologies to fill up the “last-meter” gap of video delivery to end devices such as TV sets or mobile handsets.

There are three kinds of WPAN technologies based on the data rate they are targeting on: IEEE 802.15.4 and Zigbee for low rate WPANs, IEEE 802.15.3 and Ultra-Wide Band (UWB) for high rate WPANs, and IEEE 802.15.1 and Bluetooth for the medium. Among these three, UWB is considered as the best technology for multimedia traffic, due to its high data rate (up to 480 Mbps in WiMedia UWB, potentially to Gbps), large bandwidth and low emission power [1] (i.e., less interference to other devices and more resilient to interference from others, which is preferred in a household environment).

In addition to the favorable physical-layer characteristics, WiMedia UWB also has some attractive features in its Media Access Control (MAC) layer. There are two kinds of MAC protocols supported: Prioritized Channel Access (PCA) and Distributed Reservation Protocol (DRP). PCA is extended from IEEE 802.11e Extended Distributed Channel Access (EDCA) function, with a contention-based, prioritized Quality of Service (QoS) provisioning. On the other hand, DRP is reservation-based and provides parametrized QoS, but unlike other reservation schemes, DRP allows devices to negotiate and reserve time slots without a centralized controller. Both features make UWB a primary candidate for IPTV in-home distribution, since video traffic usually has a high-bandwidth and low-delay and jitter requirement, and will need both PCA and DRP due to its highly variable data rate.

Although the WiMedia UWB has been standardized, and WiMedia-powered devices such as Wireless Universal Serial Bus (WUSB) hubs and dongles have started to appear on the market, the performance of WiMedia UWB MAC protocols is still much less explored when compared with WLANs, especially for video traffic. Unlike other hybrid MAC protocols such as IEEE 802.11e and 802.15.3, both PCA and DRP are required in WiMedia UWB, and there can be multiple clusters of PCA and DRP slots in the same superframe. In addition, there are some constraints on DRP reservation, which also affect the way how time slots are available for PCA. Therefore, the analysis of PCA performance with the presence of DRP is much more involved than EDCA alone.

In this paper, we follow the renewal reward theorem approach used in [2] to analyze the performance of WiMedia UWB PCA in both saturated and unsaturated cases, without or with the presence of DRP. The improved analysis has better accuracy and more coverage. We focus on the frame service time, i.e., the time from the instance when a PCA frame starts to content for the channel to when the frame is transmitted successfully or dropped due to reaching the retry limit, and the achievable throughput can be derived accordingly. Frame service time is of particular importance to delay-sensitive applications such as video streaming. In addition, we extend the Network Simulator (NS-2) [17] to support WiMedia MAC with UWB-specific physical-layer parameters, and the simulation results have indicated the efficacy of the analytical models and the way to better support video traffic.

The contributions of this paper are twofold. First, we build and improve in both accuracy and coverage a set of analytical models for WiMedia UWB MAC with both PCA and DRP. Although the renewal reward theorem has been employed before, no such models have been built specifically for WiMedia UWB so far. Second, this is the first time such models are validated with a commonly-used network simulator, other than just numerical calculation and in-house simulation. The models and the simulation code base provide an opportunity for the research community to further explore the performance and improvement of UWB MAC protocols.

The remainder of this paper is structured as follows. In Section II and Section III, we overview WiMedia UWB and the existing modeling and analysis work on priority-based MAC protocols. In Section IV, we detail the analytical models with both PCA and DRP in saturated and unsaturated cases. Section V presents the simulation results and validates the proposed models. In Section VI, we discuss the modeling approach and the ways for further improvement, followed by the conclusions in Section VII.
Wireless technologies are very attractive for in-door communication systems due to their convenience, flexibility and increasing affordability, evidenced by the popularity of cordless phones and WLANs. IPTV and other whole-house entertainment applications such as Personal Video Recorder (PVR) further drive the need for video streaming over short ranges in a household environment, with WLANs and WPANs as two main candidates for cross-room and in-room scenarios. However, wireless video streaming is much more challenging due to its high-bandwidth, low delay and jitter requirement.

Although IEEE 802.11a/b/g-based WLANs support raw data rate up to 54 Mbps, the achievable throughput in a household environment full of obstacles and interferers is much lower. Floors, walls, furniture, human beings and pets attenuate and reflect wireless signals, and cordless phones, microwave ovens, baby monitors, etc working in the same frequency range interfere with WLANs. Multi-hop WLANs can improve the coverage and performance to certain extent [3], but they are still not sufficient to support multiple, high-quality video streams to simple devices. Also, most WLANs products including IEEE 802.11n on the market only support contention-based MAC, and even with IEEE 802.11e prioritization, there is no performance guarantee, which is also an issue especially with a low achievable throughput.

There are several variants in IEEE 802.15 WPANs targeting on low, medium and high data rates in short ranges. Direct Sequence (DS) and Multi-Band Orthogonal Frequency Division Multiplexing (MB-OFDM) were two competing physical-layer technologies for the high rate, UWB-based IEEE 802.15.3a WPANs, but the standardization effort was then abandoned. IEEE 802.15 MAC protocols all follow superframe structures with both contention-based and contention-free periods, but there is always a need for a centralized piconet controller, which may not be feasible with mobile video devices.

WiMedia UWB outgrows from MB-OFDM UWB and has become an international standard. The current WiMedia supports up to 480 Mbps over a wide 528 MHz frequency band in 3.1 to 10.6 GHz range, with a potential to Gbps. Large bandwidth with time-frequency coding in a very large frequency range makes WiMedia UWB very resilient to narrow and even wide band interference, supporting more independent piconets in the vicinity. Low emission power also makes WiMedia UWB bring very little interface to other narrow or wide band devices. These features are very attractive in a household environment, so we focus on WiMedia UWB in this paper.

WiMedia UWB MAC also has a superframe structure, each of which lasts 65,536 milliseconds. The superframe is divided into 256 Media Access Slots (MAS), each of which has 256 microseconds. The first 32 MAS slots are used for Beacon Period (BP) and contractible, and the remaining slots are for Data Transfer Period (DTP), in which two MAC protocols are supported: contention-based PCA and contention-free DRP, and both can be used for high quality video streaming services. DRP can negotiate and reserve MAS slots for exclusive access in a distributed manner without any centralized controller, and the non-DRP slots are available for PCA, which is similar to IEEE 802.11e EDCA. In a WiMedia UWB superframe, there can be multiple, scattered DRP and PCA clusters, which is very flexible but makes the performance analysis of PCA with the presence of DRP much more involved than EDCA alone.

There are various techniques reported in the literature for the analysis of IEEE 802.11 MAC, notable among which are Markov model, equilibrium point analysis, mean value analysis. Bianchi first proposed a discrete time Markov model to obtain the saturated throughput of the Distributed Coordination Function (DCF) in IEEE 802.11 [4]. Following that, several papers appeared to extend Bianchi’s model. Ziouva and Antonakopoulos improved Bianchi’s model to derive the saturated delay [5]. Wu et al. improved Bianchi’s model to consider the rety limit [6]. Xiao and Rosdahl studied the maximum throughput and its limit [7]. Medepalli’s IEEE 802.11 throughput analysis used an average cycle time approach [8]. Besides these, Wang proposed an analytical model for IEEE 802.11 DCF using equilibrium point analysis under the unsaturated traffic condition [9].

The QoS requirement for WLAN prompted the performance analysis of IEEE 802.11e. Robinson proposed a discrete time Markov model to obtain the saturated throughput for the Enhanced DCF (EDCF) in the draft 802.11e [10]; in addition, he also considered the post-backoff waiting period in his model. Around the same time, Kong developed an analytical model of 802.11e EDCA [11], taking into account different AIFS periods, contention window sizes and virtual collision. Performance analysis of 802.11e by Xiao is an another example [12]. EDCA analysis under the unsaturated condition came out recently by Engelstad [13]. His model can predict throughput and delay under the range of light to saturated traffic load by adjusting various parameters.

The emergence of UWB also attracted attention recently due to its superiority for multimedia traffic, and quite a few research work has been done on the analysis of WiMedia UWB MAC. Wong first analyzed the UWB MAC considering DRP, beacon period and PCA [14]. His model is built on the top of a discrete time Markov chain, but he only showed the numerical throughput results for PCA with saturated traffic and did not have simulation or experimentation-based validation. Recently, a renewal reward theorem-based approach is proposed by Ling et al. to analyze EDCA-like MAC [2], but his analysis just considered PCA without DRP. In addition, he only verified his model with in-house simulation. Due to the time difference of AIFS periods between two priority classes, the pre-backoff waiting period for the lower priority traffic is largely overestimated in his model. Motivated by our experimentation work [15], we further improve their model in many aspects and verify the accuracy by using a well-known network simulator, NS-2. We also derive the frame service time for both saturated and unsaturated traffic in the presence of DRP.
Following [2], we have the following equation set

\[ P \quad \text{and the conditional collision probability} \quad \text{transmit in Zone} \ 2 \ \text{with probability} \quad \tau \quad \text{and} \quad AIFS \]

\[ \phi_{1,1}, \phi_{1,2} \text{ and } \phi_{2,1}, \phi_{2,2} \text{ can be obtained as well.} \]

1) **AC1 stations:** For a tagged AC1 station, on average it spends \( E[Z_i] = E[R_i] + E[B_1] \) generic slots to service a frame. Among these generic slots, \( E[Z_i] - (1 - \tau_1) \) of them are in Zone 1 and \( E[Z_i] - (1 - \tau_2) \) are in Zone 2.

The average length of a generic slot in Zone \( j \) (\( j = 1, 2 \)) can be obtained by \( E[S_j] = a_j + b \Delta_s \), where \( \Delta_s = AIFS_i + T_{DATA} + SIFS + T_{ACK} \) for AC1 traffic. \( a_j \) and \( b \) are the probabilities of the channel being idle and containing a successful transmission or a collision in Zone \( j \) respectively.

\[ a_1 = (1 - \tau_1)^{N_1} \]
\[ a_2 = (1 - \tau_1)^{N_1}(1 - \tau_2)^{N_2} \]
\[ b_j = (1 - a_j) \quad j = 1, 2. \]

Then the average frame service time for AC1 is given by

\[ T_1 = (E[R_i] + E[B_1] - (1 - \tau_2))E[S_1] + \phi_{1,1}E[S_1] + \phi_{1,2}E[S_2] + (1 - \tau_2)E[B_1]M \]

2) **AC2 stations:** The frame service time of a tagged AC2 station consists of two parts. The first part is the time that the AC2 station spends in Zone 2, \( T_2^* = (E[R_i] + E[B_2])E[S_2] \). The other part is called the pre-backoff waiting period as shown in Fig. 1. This period happens when at least one AC1 station transmits in Zone 1 and the tagged AC2 station does not get a chance to decrement its backoff counter at all. The transmission in Zone 1 by at least one AC1 station can happen consecutively before the tagged AC2 station decrements its backoff counter, which follows a geometric distribution. The total backoff slots of the tagged AC2 station can be divided into \( E[B_2] \) backoff segments. For each backoff segment, there are \( \phi_{1,1}/\phi_{1,2} + \phi_{2,2} \) pre-backoff waiting periods preceding the actual backoff stage. The newly defined \( \phi_{1,j} \) is introduced by us to solve the excessive overestimation problem in [2]. The average length of the pre-backoff waiting periods is given by

\[ w = (1 - a_1)\sum_{i=1}^{M}a_{i}^{i-1}(1 - i)\Delta_s/(1 - a_1^M) \]

Following [2], we have the following equation set

\[ \tau_1 = E[R_i]/(E[R_i] + E[B_1]) \quad i = 1, 2 \quad (1) \]
\[ P_i = 1 - (1 - \tau_1)^{N_1}(1 - \tau_2)^{N_2} \quad i = 1, 2 \quad (2) \]
\[ \theta_{1,2} = ((1 - \tau_1)^{N_1})M \quad (3) \]
\[ P_1 = (1 - \theta_{1,2})P_{1,1} + \theta_{1,2}P_{1,2} \quad (6) \]

where \( E[R_i] = \sum_{k=0}^{m-1} P_e^i \) and \( E[B_i] = \sum_{k=0}^{m-1} P_e^i b_k \) are the expected number of transmission trials and backoff slots experienced by a PCA frame, respectively, and \( \theta_{1,i} \) is the conditional probability for an AC1 transmission happened in Zone \( j \). Using numerical method to solve these equations, we can obtain the value of \( \tau_1, \tau_2, P_1 \) and \( P_2 \).

\[ \phi_{1,1}/\phi_{1,2} = \theta_{1,1}/\theta_{1,2} \]
\[ \phi_{1,1}/\phi_{1,2} + \phi_{2,2} = \tau_1/\tau_2 \]
\[ \phi_{1,1} + \phi_{2,2} = 1 \]

**IV. Analytical Models**

As mentioned, we focus on frame service time, the time from the instance when a data frame becomes the head of the transmission queue and eligible to access the channel to when the frame is either transmitted successfully or dropped due to reaching the retry limit. For DRP, the frame service time is bounded by the maximum DRP service interval, i.e., the gap between two consecutive DRP clusters, therefore, in this section, we only focus on the frame service time for PCA in saturated or unsaturated condition, without or with the presence of DRP. When the traffic is saturated, the achievable queue and eligible to access the channel to time is bounded by the maximum DRP service interval, i.e.,

\[ \text{due to the collision caused by simultaneous transmissions from multiple stations. All MAC frames are assumed to have the transmission error only happens when the traffic is unsaturated, the throughput is the same as the offered load.} \]

To obtain the frame service time for PCA, we have followed the approach used in [2]. The network we have considered in this model is a piconet where every station can hear each other and there are no hidden terminal problems. Time is discretized into generic slots, which may have different lengths \( \delta \) or \( \Delta \), depending on whether the channel is idle or busy (either successful transmission or collision). All the stations are assumed to be time-synchronized and they can correctly sense the channel at the beginning of a slot. Wireless channel is considered to be ideal, and transmission error only happens due to the collision caused by simultaneous transmissions from multiple stations. All MAC frames are assumed to have the same length and only two classes of traffic are considered (i.e., AC1 and AC2). However, different frame length and more traffic classes can be incorporated in this analysis as well.

**A. Saturated PCA without DRP**

As shown in Fig. 1, there are \( N_1 \) AC1 stations and \( N_2 \) AC2 stations with Arbitration Inter-Frame Spacing AIFS1 and AIFS2, respectively, where \( \text{AIFS}_2 - \text{AIFS}_1 = M \delta \). Between two AIFS periods, there are three possible scenarios: AC1 stations transmit in Zone 1 with probability \( \phi_{1,1} \), where AC2 stations are still in their AIFS2 period; AC1 stations transmit in Zone 2 with probability \( \phi_{1,2} \), where both AC1 and AC2 stations have finished their AIFS periods; AC2 stations transmit in Zone 2 with probability \( \phi_{2,2} \).

In order to obtain the frame service time, we need to find two key probabilities: the transmission probability \( \tau_i \) and the conditional collision probability \( P_i \) for ACi stations. Following [2], we have the following equation set

\[ \tau_i = E[R_i]/(E[R_i] + E[B_1]) \quad i = 1, 2 \quad (1) \]
\[ P_i = 1 - (1 - \tau_1)^{N_1}(1 - \tau_2)^{N_2} \quad i = 1, 2 \quad (2) \]
If the inter-arrival time of DRP clusters in a superframe is constant or exponentially distributed with rate $\omega$, the expected number of DRP clusters experienced by the tagged $AC_i$ station is $D_i = T_i/\omega$. If the length of each DRP cluster is $L$, the frame service time in the presence of DRP can be estimated by

$$
\zeta_i = T_i + D_i L + D_i AIFS_i + E[R_i]T_Q,
$$

where $T_Q$ is the sum of data frame transmission time, acknowledgment frame transmission time, SIFS and guard time, since as shown in Fig. 1, the station has to hold on if the remaining time to the next DRP cluster is not sufficient for the entire frame.

### C. Unsaturated PCA with DRP

The difference between the saturated and unsaturated case is that in the former, there is always at least one packet in the transmission queue, whereas in the latter, the queue might be empty from time to time and the achievable throughput is the offered load. Station busy probability is 1 in saturated case and this is considered as the upper bound, beyond which packets begin to accumulate in the queue. In our analysis, all symbols for the unsaturated case are superscripted by $'$. If the frame arrival rates in a random slot of $AC_1$ and $AC_2$ stations are $\lambda_1$ and $\lambda_2$, the busy probabilities for $AC_1$ and $AC_2$ stations are given by $p_1 = T_1'\lambda_1$ and $p_2 = T_2'\lambda_2$, respectively.

Note that $T_1'$ and $T_2'$ are the frame service time for $AC_1$ and $AC_2$ stations, respectively. Following [2], the equation set of transmission probability and collision probability is given

$$
P'_{1,2} = 1 - (1 - \rho_1\tau_1')^{N_1}(1 - \rho_2\tau_2')^{N_2-1}
$$

$$
P'_{1,1} = 1 - (1 - \rho_1\tau_1')^{N_1-1}
$$

$$
P'_{1,2} = 1 - (1 - \rho_1\tau_1')^{N_1-1}(1 - \rho_2\tau_2')^{N_2}
$$

$$
\theta'_{1,2} = ((1 - \rho_1\tau_1')^{N_1-1}(1 - \tau_2'))^M
$$

$$
P'_{1} = (1 - \theta'_{1,2})P'_{1,1} + \theta'_{1,2}P'_{1,2}
$$

To get the generic slot length, we need to know the probability of a particular slot being idle and in unsaturated case, a slot can be idle due to no traffic, which should not be taken into account in frame service time. We assume an $AC_1$ station tends to transmit in Zone 1, and the probability of a slot being idle in Zone 1 is $a'_{1,1} = (1 - \tau_1')(1 - \rho_1\tau_1')^{N_1-1}$. If the $AC_1$ station tends to transmit in Zone 2, the probability of a slot being idle in Zone 2 is $a'_{2,1} = (1 - \tau_2')(1 - \rho_1\tau_1')^{N_1-1}(1 - \rho_2\tau_2')^{N_2}$. Therefore, the generic slot length in Zone 1 and Zone 2 for $AC_1$ stations can be computed by $E[S'_{1,1}] = a'_{1,1}\delta + (1 - a'_{1,1})\Delta_1$ and $E[S'_{1,2}] = a'_{2,1}\delta + (1 - a'_{2,1})\Delta_1$, respectively.

Similarly, if an $AC_2$ station tends to transmit in Zone 2, the probability of a slot being idle in Zone 2 due to backoff is $a'_{2,2} = (1 - \tau_2')(1 - \rho_1\tau_1')^{N_1}(1 - \rho_2\tau_2')^{N_2-1}$. The generic slot computation for $AC_2$ is the same as $AC_1$ in Zone 2, which is given by $E[S'_{2,2}] = a'_{2,2}\delta + (1 - a'_{2,2})\Delta_2$.

The frame service time for $AC_1$ stations and the first part of the frame service time for $AC_2$ stations can be derived in the same way as that in the saturated case.

### V. Performance Evaluation

To verify the accuracy of the analytical models, we have done extensive simulation in NS-2. Since NS-2 does not have the module for WiMedia UWB MAC layer and PCA is similar to IEEE 802.11e, we have modified TKN’s EDCA code [17] to simulate the behavior of WiMedia UWB MAC. We have also modified the IEEE 802.11 physical layer module in NS-2 to emulate the MB-OFDM UWB physical layer. We used the free-space propagation model with ideal channel condition in simulation. All the parameters we have used for validation are listed in Table I. We assume the number of $AC_1$ and $AC_2$ stations is the same, i.e., $N_1 = N_2$, and the frame arrival events at each station follow a Poisson process.
A. PCA Performance without DRP

Figure 2 shows the frame service time affected by the increased frame arrival rate. The number of contending stations in this scenario is \(N_1 = N_2 = 9\). When the frame arrival rate is low, the channel becomes idle from time to time due to no traffic. Therefore, there is a low chance to have collisions with other frames from other stations, and thus the frame service time is pretty low (i.e., dominated by frame transmission time) for both \(AC_1\) and \(AC_2\) stations.

As the offered load is increased, we observe an increased frame service time due to the increased number of collisions. The increased offered load affects the low priority traffic more than the high priority traffic. This is because as the offered load is increased, there is a higher chance that \(AC_1\) stations have frames to transmit, which in turn increases the probability that at least one \(AC_1\) station transmits in Zone 1. This scenario increases the likelihood of pre-backoff waiting periods for \(AC_2\) stations and ultimately their frame service time. Due to the increased frame service time, with the same offered load \(AC_2\) stations become saturated earlier than \(AC_1\) stations, as being pointed out in the figure. After \(AC_2\) stations are saturated, with the increased offered load and more collisions, the frame service time for \(AC_1\) stations is increased as well but much slower when compared with \(AC_2\) stations. If we further increase the offered load, \(AC_1\) stations get saturated eventually as well. At this point we see the maximum frame service time for both classes of stations, beyond which they will experience excessive queuing delay. This figure also shows that our improved analytical models provide a much tighter upper bound than the ones in [2], especially for \(AC_2\) stations, in both unsaturated and saturated cases.

Figure 3 shows that simulation results are in good agreement with the analytical ones as the total number of stations \((N_1 + N_2)\) is increased when the offered load is 0.004 frames/slot/station. As the number of stations increases, frame service time increases as well since the larger the number of stations the larger the number of collisions, and eventually it results in an increased frame service time. This figure illustrates again that low priority stations are more affected in terms of the increased frame service time than high priority ones. This is because as the number of \(AC_1\) stations is increased, the probability that at least one \(AC_1\) station transmits in Zone 1 also increases, which causes again an increased likelihood of pre-backoff waiting periods for \(AC_2\) stations and ultimately their frame service time. This figure also shows our models give better prediction than [2], even at a very low load.

B. PCA Performance with DRP

In order to see the effect of DRP on PCA frame service time, we put some hard DRP clusters in a superframe with different
DRP reservation percentage: 6.25%, 12.5%, 25% and 50%. These DRP clusters are evenly distributed in the superframe in isozone 3, 2, 1 and 0, respectively, which are defined in [16]. The frame transmission over DRP is deterministic and the delay is guaranteed. Except the portion reserved for DRP, the rest of the DTP in the superframe is available for PCA. In our simulation, during DRP periods all PCA stations keep silent, and after the DRP periods, they start their usual activities again (backoff, transmission, etc). The number of PCA stations for this scenario is also $N_1 = N_2 = 9$.

The results in Fig. 4 and Fig. 5 compare the frame service time in the presence of DRP at different percentage for $AC_1$ and $AC_2$ stations, respectively. In these two figures we gradually increase the frame arrival rate and plot the corresponding frame service time. When there are more DRP clusters, the PCA frame service time is increased accordingly since there is less time available for PCA and therefore it takes a longer time to have a successful frame transmission. These figures again point out that at the same offered load, $AC_2$ stations with a higher percentage of DRP get saturated much earlier, due to the increased number of pre-backoff waiting periods caused by the increased offered load and resultant increased number of collisions, as well as less available PCA time. If the percentage of DRP is $X$ and if the frame service time is $T$ when the whole DTP is available for PCA, at the system saturated point (when both classes of stations get saturated), the frame service time in the presence of DRP is approximately $T/(1-X)$, which has been reflected in these figures as well. Saturated service time in the presence of DRP, shown in dotted lines, also matches the numerical results from our analysis. At a very low offered load, the frame service time in the presence of DRP mainly depends on DRP cluster length. This is because at a very low load the frame service time without DRP is usually pretty low, and occasionally if any frame transmission is postponed by a DRP cluster, the length of that DRP cluster dominates the overall PCA frame service time.

VI. FURTHER DISCUSSION

So far, we have exhibited with simulation the effectiveness of our improved analytical models for WiMedia UWB MAC. Using the proposed analytical and simulation models, together with the experimentation results we had in [15], we have shown the performance tradeoff between PCA and DRP and their impact on each other in terms of DRP reservation percentage and pattern. To improve system utilization and QoS provisioning, it is possible to use both DRP and PCA to transport different portion of a high-quality, variable bitrate video stream in IPTV in-home distribution networks.

Our analytical models can capture the PCA performance very closely in both saturated and unsaturated cases. With the presence of DRP, our models still can provide a close upper bound on the frame service time in the saturated case. However, the analytical model for unsaturated PCA with the presence of DRP is still an approximation and needs further work, although the simulation results have shown the approximation is actually quite reasonable as well.

Since UWB is targeted for IPTV in-room access due to its high data rate and low power emission, transmitting video streams over UWB is another future work. Currently our models assume only one access category traffic exists at each station, however in real IPTV in-room networks multiple categories may exist at the same station. Therefore we plan to extend our models for heterogeneous traffic as well.

VII. CONCLUSIONS

In this paper we have followed the renewal reward theorem-based approach used by Ling et al. in [2] and further improved their modeling techniques, particularly of our interest for WiMedia UWB PCA performance in the presence of DRP. In addition to model correction and extension, we have verified our improved models with the commonly-used NS-2, and shown that our models can provide a much tighter upper bound on the frame service time, especially for the lower priority traffic. The frame service time is important for delay-sensitive applications such as IPTV and PVR, and the tighter bound can allow a more efficient utilization of system resources.

REFERENCES