eDOAS: Energy-Aware Device-Oriented Adaptive Multimedia Scheme for Wi-Fi Offload

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***Abstract*—Mobile devices became an essential part of every person daily routine enabling them to browse the Internet, watch videos, work and play online anytime and anywhere. However this led to a tremendous growth in user generated data traffic putting significant pressure on the underling network technology. Thus, in order to cope with this explosion of data traffic, Wi-Fi offload became a popular solution for network operators. The solution enables the network operators to accommodate more mobile users and keep up with their traffic demands. Moreover, with the energy conservation becoming a critical issue around the world, it provides motivation for this paper to propose an Energy-aware Device-Oriented Adaptive multimedia Scheme (eDOAS) for Wi-Fi Data Offload. eDOAS adapts the interactive multimedia application to the underlying Wi-Fi network conditions, device characteristics and device energy consumption, in order to prolong the battery lifetime of the mobile device and maintain an acceptable user perceived quality level. Real test-bed energy consumption measurements were conducted on five different devices and the performance of eDOAS was analyzed against other schemes from the literature, in terms of energy consumption, service outage, average throughput, packet loss and PSNR.**

***Index Terms* — Energy Consumption, Wi-Fi Offload, Adaptive Multimedia**

I. Introduction

The 3GPP 4th generation cellular technologies – LTE (Release 8) and LTE-Advanced (Release 10) networks have been commercially launched and adopted by many network carriers and vendors. 216 commercial LTE networks were deployed to date, and the number of LTE subscriptions reached up to 126.1 million with 350% annual growth [1]. Additionally, the adoption of the femtocell technology for UMTS and WiMAX [2] aimed at improving the coverage, capacity and reliability of the traditional macrocells. Furthermore, the LTE femtocell technology will be integrated into the LTE-A systems in the foreseeable future. However, with the rapid evolution towards next generation cellular networks, the network operators will face the problem of high infrastructure deployment cost. Therefore, a cost-efficient high-capacity enabler technique, mobile data offloading, has been a key area of study in 3GPP Release-10 [3]. Because of the all-IP network architecture and technical similarity between LTE femtocell and Wi-Fi networks, it is fairly easy to integrate the data offloading from LTE networks to WLAN networks (e.g. IEEE 802.11 protocols), compared with previous 3GPP networks (e.g. GSM, UMTS). To this end, many network operators are starting to integrate Wi-Fi as another radio network to 3GPP mobile core, as shown in Fig. 1. This solution enables the transfer of some traffic from the core cellular network to Wi-Fi at peak times, and key locations (e.g., home Wi-Fi, Office Wi-Fi, Public HotSpot, etc). The Wi-Fi offload solution is already adopted by many service providers. For example, O2 in United Kingdom offers the TU Go[1] application to their customers enabling them to use their O2 mobile number to call or text over the Wi-Fi network. In this way users can avail of a wider service offering.

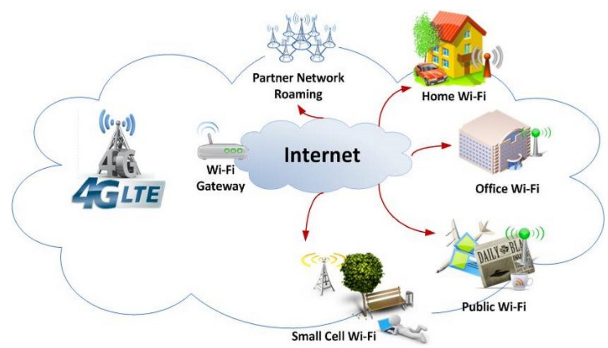

Fig. 1. Wi-Fi Offload - Example Scenario

However, the overall experience is still far from optimal as providing high quality mobile video services with QoS (Quality of Service) provisioning over resource constrained wireless networks remains a challenge. Moreover, user mobility, as well as the heterogeneity of mobile devices (e.g., different operating systems, display size, CPU capabilities, battery limitations, etc.), and the wide range of the video-centric applications (e.g. VoD (Video On Demand), video games, live video streaming, video conferences, surveillance, etc.) opens up the demand for user-centric solutions that adapt the application to the underlying network conditions and device characteristics.

In order to guarantee QoS for multimedia services, many adaptive mechanisms were proposed and adopted. A well-known dynamic http-based adaptive multimedia scheme, MPEG-DASH, is standardized in [4]. MPEG-DASH adapts the multimedia streams based on the network conditions, enabling smooth video streaming to their clients.

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[1] TU Go - http://www.o2.co.uk/tugo/

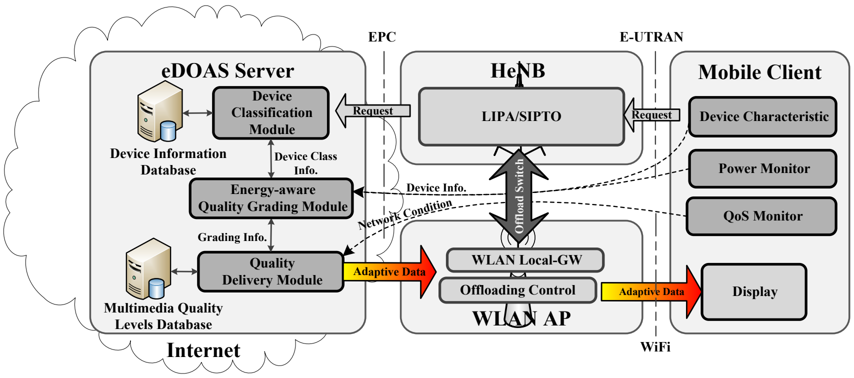

Fig. 2. Energy-Aware Device-Oriented Adaptation Scheme - Framework

In our previous work we proposed DOAS, a Device-Oriented Adaptive multimedia Scheme for LTE networks [5]. DOAS is built on top of the LTE downlink scheduling mechanism, and adapts the video streams based on the mobile device characteristics (e.g. screen resolution) while maintaining an acceptable user perceived quality level. However, the energy consumption of the mobile devices was not considered. A battery and stream-aware dynamic multimedia control mechanism (BaSe-AMy) was proposed in [6]. BaSe-AMy monitors the power consumption of the mobile device and lowers the stream quality if the battery lifetime is not enough to finish the video playout. However the device heterogeneity is not considered. Most of the adaptive schemes proposed in the literature are either network-aware or QoS-based.

Despite the amount of research done in this area, not much focus has been placed on the impact of device heterogeneity on the energy consumption for multimedia transmission over a wireless environment. To this end, we propose an enhanced Energy-aware DOAS (eDOAS) for Wi-Fi offload, which enables the dynamic adaptation of multimedia delivery to the mobile clients based on their device characteristics, energy consumption and underlying network conditions, in order to improve the Quality of Experience (QoE) and prolong the battery lifetime of the mobile device. eDOAS classifies the devices in different categories based on their resolutions and by using a real test-bed measurement setup we measure the energy consumption of each device class. The real test-bed measurements are incorporated into the mathematical energy consumption model of eDOAS for each device class.

II. eDOAS: Energy-aware Device-Oriented Adaptive Multimedia Scheme

A. eDOAS Framework

eDOAS framework is illustrated in Fig. 2 and consists of two main parts: the Mobile Client or UE and the eDOAS server. The exchange of information between the two components is enabled by the LTE femtocell Home-eNodeB (HeNB) and WLAN Access Point (Wi-Fi AP).

The UE side includes several essential functional modules: (1) *Device Characteristic* - stores the device characteristics (e.g. screen resolution, screen brightness, operating system); (2) *Power Monitor* - monitors the device battery and sends the battery-related information (e.g., battery remaining capacity, energy consumption rate, etc.) to the eDOAS server once the mobile user requests a multimedia service; (3) *QoS Monitor* - periodically provides network condition information to the eDOAS server via Evolved Packet System bearer [7]; (4) *Display* - enables the presentation of the multimedia content.

The LTE femtocell HeNB undertakes the basic functionalities of LTE eNodeB, and manages the data offload by switching from the cellular network to WLAN. The data offload function is defined in 3GPP Release-10 and includes an important module: Local IP Access and Selected IP Traffic Offload (LIPA/SIPTO) [3] which provide a local gateway and data offloading tunnel for UEs and other networks connected to the same HeNB. It is assumed that the IP-based multimedia streams are offloaded from LTE HeNB to the WLAN network, and the HeNB just maintains the basic IMS signaling services. The role of the offloading control module in WLAN AP is to manage the offloaded traffic from HeNB.

As illustrated in Fig. 2, the eDOAS server side is divided into three functional modules: (1) *Device Classification Module* - classifies the attached mobile devices based on the device information feedback (e.g. screen resolution) by using a Mobile Device Classification Scheme (MDCS), and then stores the classified information in the database; (2) *Energy-aware Quality Grading Module* – uses an Energy-aware Video Quality Grading Scheme (eVQGS) to grade a set of video quality levels based on device battery information; (3) *Quality Delivery Module* - selects and delivers a multimedia quality level from the Multimedia Quality Levels Database based on the Video Quality Delivery Control Scheme (VQDCS).

B. Mobile Device Classification Scheme (MDCS)

MDCS classifies the mobile devices into five classes based on the device characteristics (i.e., device screen resolution) as described in [5] and listed in Table I.

TABLE I. Classification of Mobile Device Based on Screen Resolutions

Device Classes	Class 1	Class 2	Class 3	Class 4	Class 5
Resolution	≥1024×768	(1024×768, 768×480]	(768×480, 480×360]	(480×360, 320×240]	<320×240

C. Energy-aware Video Quality Grading Scheme (eVQGS)

eVQGS consists of two mechanisms: (1) the basic video quality grading mechanism and (2) the energy-aware video quality grading mechanism. The basic video quality grading mechanism allocates an adequate set of video clips with different quality levels to the corresponding devices [5]. For

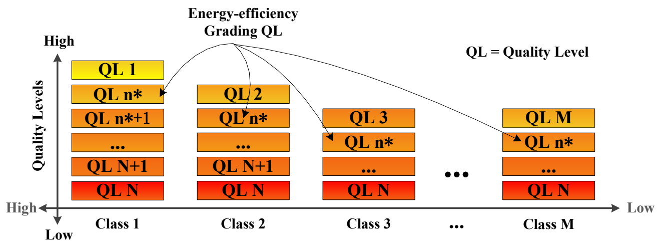

Fig. 3. Video Quality Level Allocation List

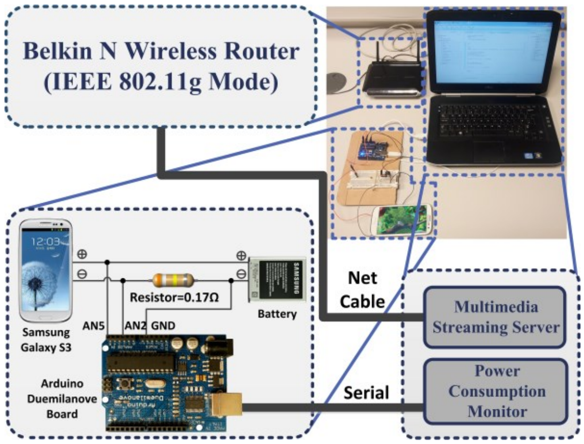

Fig. 4. Experimental Test-Bed Setup

example, a set of different video quality levels (e.g. different bitrates, resolution, frame rate, etc.) starting from QL1, the highest quality level to QL N, the lowest quality level, aredefined for Class 1. Similarly, the set of video clips from M to N are assigned to the devices in Class M. The set of video quality levels allocated to each device class is listed in Fig. 3.

The mobile device battery lifetime is estimated using its remaining battery capacity, energy consumption rate and working voltage as in (1):

$$\mu[\sec] = C_B[mAh] \times U_B[V] \times 3600 \Big/ P[mW] \qquad (1)$$

where μ is the battery lifetime, C_B and U_B represent the battery capacity and battery voltage, respectively. The average power consumption P of a mobile device playing a video clip is computed using (2) [8].

$$P = \frac{E_J}{\lambda} = \frac{r_d \cdot D + r_t \cdot T + c}{\lambda} = r_d \cdot R + r_t + c \qquad (2)$$

where E_J is the consumed energy (Joule), λ is the duration of the video clip (seconds), T is the average time of energy consumption measurement (seconds); r_d is the energy consumption rate for data (Joule/Mbit), and r_t is the energy consumption per time unit (Watt); the total data of the received video clip is D (Mbit) and the average bitrate of the video clip is R (Mbps); c is a constant (no unit). r_d, r_t, and c are computed using real test-bed energy consumption measurements for each device class as described in Section III.

The energy-aware video quality grading mechanism adapts the multimedia streams based on the remaining battery capacity of the mobile device. Therefore, when a mobile user is requesting a video with a length longer than the mobile device battery lifetime, the best energy-efficiency grading quality level will be selected from the allocation list assigned by the basic

TABLE II. LIST OF MOBILE DEVICES USED FOR POWER MEASUREMENT

Device Classes	Class 1	Class 2	Class 3	Class 4	Class 5
Device Model	Samsung Galaxy S3	Viliv X70 EX	HTC Google Nexus One	Vodafone Smart Mini	Vodafone 858 Smart
Operating System	Android 4.2	Windows XP	Android 2.3.4	Android 4.2	Android 4.1
Screen Type	Super AMOLED	WSVGA	AMOLED	TFT	TFT
Resolution	720×1280	1024×600	480×800	320×480	240×320
Battery Capacity	2100 mAh	3920 mAh	1330 mAh	1400 mAh	1200 mAh
Battery Voltage	3.8 V	7.4 V	3.7 V	3.7 V	3.7 V

video quality grading mechanism as indicated in (3).

$$QL_{n^*} :\Leftrightarrow R_m^{n^*} = \underset{R \in \left(0, R_m^M\right]}{\arg\min}\, \mu(R) = \left\{ R \middle| \mu(R) \ge \lambda \cdot 1.10 \right\} \qquad (3)$$

where $\mu(R)$ represents the battery lifetime of the mobile device for a bitrate R of the multimedia stream, QL_{n^*} is the best energy-efficiency grading quality level which ensures that the mobile user has enough battery lifetime to finish the video playout, R^{n^*} represents the bitrate of QL_{n^*}; $m \in \{1,2,3,\ldots,M\}$ and represents the class index. For example, the highest quality level of a Class 2 mobile device is QL_2 as listed in Fig. 3; n represents the quality level index $M \le n < n+1 \le N$. Considering the fact that the mobile user might still want to use the mobile device after the video playout finished, the estimated battery lifetime is selected as ($1.10 \cdot \lambda$).

D. *Video Quality Delivery Control Scheme (VQDCS)*

After the best energy-efficiency grading quality level QL_{n^*} is selected by eVQGS, the VQDCS adapts the multimedia stream to the current QoS conditions. If the available channel bandwidth is good enough, VQDCS will adapt the QL^* to the corresponding quality level. If the available bandwidth becomes low, the VQDCS will adapt down the quality level from QL_{n^*} to QL_N. This is done using (4).

$$QL^* = \begin{cases} QL_{n^*}, & if\ r_{m,k} \in \left[R_m^{n^*}, +\infty\right) \\ QL_{n^*+1}, & if\ r_{m,k} \in \left[R_m^{n^*+1}, R_m^{n^*}\right) \\ QL_N, & if\ r_{m,k} \in \left(0, R_m^N\right) \end{cases} \qquad (4)$$

where $r_{m,k}$ is the available video bitrate of the k^{th} mobile device in Class m , which is computed using (5).

$$r_{m,k}(t) = \Phi_{Avail}(t) \times \frac{R_m^{n^*}}{\sum_{m=1}\sum_{k=1} R_{m,k}^{n^*}} \qquad (5)$$

where Φ_{Avail} is the available system bandwidth at time instant t; $k \in \{1,2,\ldots,K\}$ is the device index within the Class.

III. EXPERIMENTAL TEST-BED SETUP

The experimental test-bed setup is illustrated in Fig. 4 and consists of: (1) Belkin N wireless router running on Channel 13 (2.472GHz) IEEE 802.11g mode; (2) several mobile devices, one device from each defined class; (3) Arduino Duemilanove Board that measures the mobile device power consumption;

TABLE III-A. LIST OF MULTIMEDIA STREAMS AND MEASUREMENT RESULTS FOR CLASS 1 AND CLASS 2

Devices	Class 1						Class 2				
Quality Levels	**QL1**	**QL2**	**QL3**	**QL4**	**QL5**	**QL6**	**QL2**	**QL3**	**QL4**	**QL5**	**QL6**
Format	H.264/MPEG-4 AVC Baseline Profile, Duration = 597 seconds										
Resolution	1280×720	800×448	512×228	320×176	320×176	320×176	1008×608	608×368	400×240	400×240	400×240
Bitrate [kbps]	3840	1920	960	480	240	120	1920	960	480	240	120
Frame Rate [fps]	30	30	25	20	15	10	30	25	20	15	10
Avg. Power Consumption [mW]	1379	1210	916	894	832	763	4271	3840	3391	3344	3146
Avg. Energy [Joule]	822	721	546	533	495	455	2545	2288	2012	1992	1875
Battery Lifetime [seconds]	20826	23732	31348	32121	34528	37618	24452	27193	30794	31233	33193
r_d **[Joule/Mbps]**	0.1655						0.6248				
r_t **[W]**	0.7438						3.0711				

TABLE III-B. LIST OF MULTIMEDIA STREAMS AND MEASUREMENT RESULTS FOR CLASS 3, CLASS 4 AND CLASS 5

Devices	Class 3				Class 4			Class5	
Quality Levels	**QL3**	**QL4**	**QL5**	**QL6**	**QL4**	**QL5**	**QL6**	**QL5**	**QL6**
Video Format	H.264/MPEG-4 AVC Baseline Profile, Duration = 597 seconds								
Resolution	512×288	320×176	320×176	320×176	480×320	300×200	300×200	320×240	320×240
Bitrate [kbps]	960	480	240	120	480	240	120	240	120
Frame Rate [fps]	25	20	15	10	20	15	10	15	10
Avg. Power Consumption [mW]	953	799	726	666	648	622	601	576	481
Avg. Energy [Joule]	567	476	433	397	387	371	359	343	287
Battery Lifetime [seconds]	18589	22172	24402	26600	28739	29969	31001	27738	33189
r_d **[Joule/Mbps]**	0.3427				0.1315			0.7886	
r_t **[W]**	0.6240				0.5857			0.3870	

(4) laptop that stores the measurements, computes the energy consumption and runs the multimedia server.

The aim of the experimental test-bed is threefold: (1) Study the impact of different device classes on the energy consumption. (2) Study the impact of different video quality levels on each device class. (3) Compute r_d [Joule/Kbyte], r_t [W] and the constant c for each device class, in order to model the energy consumption in the simulation environment.

A. Power Measurement Setup

As in Fig. 4, the power measurement setup consists of a mobile device, Arduino Board, and a low value resistor. The high-precision resistor is connected in series between the negative of the battery terminal and its connector on the mobile device. The Arduino board measures the battery voltage and the resistor voltage drop and sends them to the power consumption monitor, a Java application running on the laptop. Using the voltage values, the device power consumption (using Ohm's Law) is computed. The measurements were conducted for each device class with the device characteristics listed in Table II. During the experiments, the devices' configuration settings and all the background applications were kept constant and minimal for each device class.

B. Multimedia Streaming Server

The multimedia server streams the multimedia content through the wireless network to the mobile device. For this purpose, a 10 minute long animation movie, Big Buck Bunny, was used. The video clip was transcoded into several different quality levels for each device class and stored on the server. Table III lists the encoding parameters and characteristics of each multimedia quality level for each device class. In order to reduce the impact of the device display brightness on the power consumption, the brightness level for all devices in each experiment was set to 30%. Each individual measurement experiment was repeated three times, with a total of 60 tests being performed. The results were collected and the average values for power consumption, energy and battery lifetime were computed as listed in Table III. From all these experimental tests the values r_d [Joule/Kbyte] and r_t [W], are computed as indicated in Table III. Following the mathematical computation the value of the constant c was found to be 0. These values will be used for the mathematical model of the energy consumption, in the simulation scenarios, in order to provide more accurate results. The results in Table III show that the device consumes more energy in case of high bitrate stream and the battery lifetime is impacted by the battery capacity and power consumption rate. It can be noticed that Class 2 device has the highest energy consumption. This is because it runs Windows XP, and has a higher battery capacity and voltage when compared to the other Android-based devices.

IV. PERFORMANCE EVALUATION

This section describes the performance evaluation of eDOAS compared against DOAS [5] and BaSe-AMy [6]. DOAS was implemented so that it adapts the stream based on device classification, without considering the energy component whereas BaSe-AMy adapts the multimedia stream based on the battery level of the mobile device and network conditions. The decision mechanism in BaSe-AMy designs several battery thresholds (e.g. percentage of the remaining battery capacity=10% or 30%) and one packet loss threshold (e.g. loss ratio=10%). When the video playout is shorter than the battery lifetime, and remaining battery capacity is above 30% and loss ratio is below 10%, the multimedia server will stream the highest quality level. Whereas, when the video playout is longer than the battery lifetime, and any other threshold cannot be satisfied, then the server streams a lower quality level. In order to provide a fair comparison, 6 video quality levels (e.g. 3840kbps, 1920kbps, 960kbps, 480kbps, 240kbps and 120kbps), 5 remaining battery capacity thresholds (e.g. 90%, 70%, 50%, 30% and 10%) and 10% loss threshold are configured for BaSe-AMy. The main characteristics of all the considered adaptive schemes are summarized in Table IV.

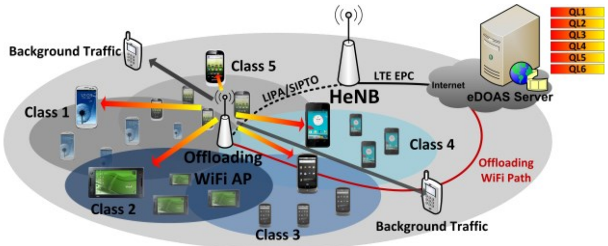

Fig. 5. Scenario 2 – Network Simulation

TABLE IV. CHARACTERISTICS OF THE ADAPTIVE SCHEME

	Device-Oriented	Energy-aware
DOAS	YES	NO
BaSe-AMy	NO	YES
eDOAS	YES	YES

TABLE V. SIMULATION PARAMETERS

Parameter	Value
Simulation Length	12000 seconds
Number of Mobile Devices	Total 30 Devices ;5 Classes; 6 Devices in each Class
Cell Layout	Single Cell; Radius = 100 meters
Wi-Fi Mode	IEEE 802.11g
Antenna Model	Isotropic Antenna Model
Path Loss Model	Friis Propagation Model
Traffic Model	CBR (3840kbps, 1920kbps, 960kbps, 480kbps, 240kbps, 120kbps); Background Traffic

A. Scenario 1 – Energy-aware Evaluation

This scenario was setup using MATLAB to evaluate the energy-aware performance of the three adaptive schemes, considering an ideal network environment (no congestion). The server delivers the 12000-second long video streams encoded at 6 quality levels to five different mobile devices (one from each defined class) with their remaining battery capacity decreasing (e.g. from 100% to 10%, step=10%). When the remaining battery capacity is less than the lowest video quality playout, it is considered that the multimedia streaming service reached the outage state.

B. Scenario 2 – Network Simulation

In Scenario 2, LTE-Sim [9], a near-real simulation platform was used the performance evaluation of eDOAS against the other two adaptive schemes in terms of average throughput, packet loss ratio, PSNR and energy consumption. The simulation scenario is illustrated in Fig. 5 and it was build using the information from the real experimental test-bed environment. An IEEE 802.11g AP serves a number of 30 mobile devices performing video streaming. The devices are divided into five classes as previously explained. Each device class has its own power consumption model for real-time multimedia transmission with the energy parameter values r_d and r_t obtained from the experimental test-bed as listed in Table III. The geographical location of the mobile devices is randomly generated in a single cell with 100 meters radius. A multimedia server stores the multimedia content encoded at different quality levels. Depending on the adaptive schemes (i.e., eDOAS, DOAS or BaSe-AMy), the server adapts the multimedia stream to the devices accordingly. The details of the simulation environment are listed in Table V.

TABLE VI. BACKGROUND TRAFFIC MODEL PARAMETERS

	Distribution Parameters
Duration of Occurrence	α=1.2; k=7; m=15; mean≈10(seconds)
Utilization of Background Traffic	Min=5%;Max=95%

Extra mobile users are considered to generate background traffic at random periods during the simulation. 1200 occurrences of background traffic were generated during the simulation length based on the truncated Pareto Distribution Model [10], with probability density function computed as in (6). The variability of the background traffic is simulated by using the Uniform Distribution. The parameters of both distributions as listed in Table VI.

$$f_X(x)=\begin{cases}\dfrac{\alpha\cdot k^{\alpha}}{x^{\alpha+1}}, k\le x\le m\\ \left(\dfrac{k}{m}\right)^{\alpha}, x=m\end{cases} \tag{6}$$

V. RESULTS AND ANALYSIS

Scenario 1 analyzes the energy-aware performance in terms of average energy consumption and average outage probability of multimedia service at different remaining battery capacity states (e.g. from 100% to 10%) as listed in Fig. 6 and Fig. 7. It is noticed that by using a device-oriented adaptive mechanism (eDOAS or DOAS), the energy consumption is reduced up to 11% when compared with a non-device-oriented scheme as BaSe-AMy. This is because the device-oriented schemes adapt the video quality requirements according to the device type. For example, for a low resolution device sending a high resolution multimedia stream will waste the energy of the mobile device without any visible benefits in terms of quality. Additionally, when compared with the non-energy-aware DOAS, eDOAS saves at least 5% energy. This is because eDOAS adapts to a lower video quality level when the remaining device battery capacity is dropping. This will ensure that users will finish watching the video stream with the reaming battery capacity as illustrated in Fig. 6. Therefore, eDOAS prolongs the battery of the mobile device as compared to DOAS.

Considering the results from Scenario 2, Fig. 8 illustrates the averaged throughput for each mobile device class. As this scenario considers variations in network congestion and decreasing battery capacity, eDOAS adapts the video quality level according to the dynamic network conditions and remaining battery capacity of each device. Therefore when compared to BaSe-AMy and DOAS, eDOAS lowers the bitrate of the adaptive streams (as seen in Fig. 8) to save more energy and bandwidth resources. Moreover, eDOAS reduces with at least 38% the packet loss rate (e.g., Class 4) as listed in Fig. 9. For example, the battery capacity of Class 3 device (e.g. HTC Nexus One) is lower than the other devices thus its energy consumption rate is higher when compared with the devices in Class 1, 2 and 4. Therefore it adapts to a lower video quality stream when using eDOAS so the throughput and packet loss for this device class are lower than for other classes.

The Peak Signal-to-Noise Ratio (PSNR) was computed based on the estimation method in [11] to assess the quality of the received multimedia stream as listed in Fig. 10. For example, when using eDOAS, Class 1 devices achieve 20dB and 4dB increase in PSNR when compared to BaSe-AMy and DOAS, respectively. It can be noticed that eDOAS finds the bet trade-off between energy vs. quality. Even though DOAS ensures good PSNR as well, the outage probability is very high, meaning that the battery will end before the video playout.

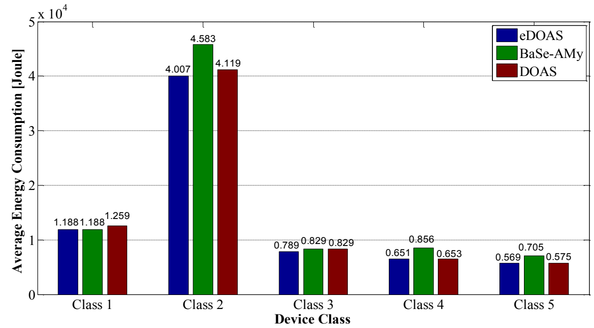

Fig. 6. Average Energy Consumption [1×10^4 Joule]

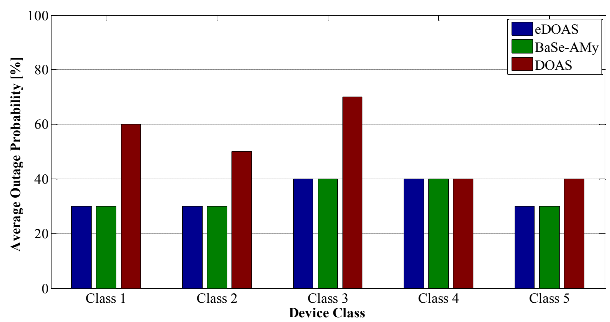

Fig. 7. Average Outage Probability of Multimedia Stream [%]

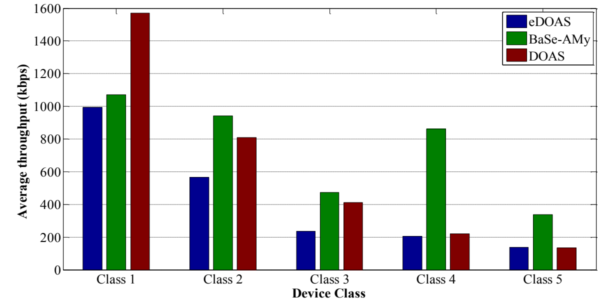

Fig. 8. Average Throughput [kbps]

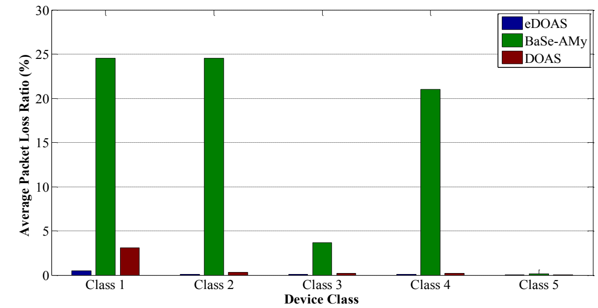

Fig. 9. Average Packet Loss Ratio [%]

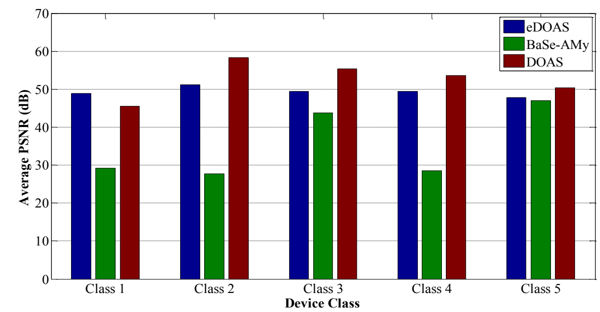

Fig. 10. Average PSNR [dB]

VI. Conclusions

This paper proposes eDOAS, an **E**nergy-aware **D**evice-**O**riented **A**daptive multimedia **S**cheme that makes use of the mobile device heterogeneity in order to provide smooth energy-aware adaptive streaming to mobile devices within a Wi-Fi offload scenario. A real experimental test-bed was setup and energy measurements were conducted when streaming different video quality levels to five mobile devices, each representing a different device class. A total of 60 measurements tests were conducted with three main goals: (1) to study the impact of device heterogeneity on the energy consumption, (2) to study the impact of different quality levels on the energy consumption, and (3) to compute the energy consumption rate for data/received stream and the energy consumption per unit of time for each device class, which were then used for the mathematical energy model in the simulation environment. The evaluation results show the benefits of eDOAS in comparison with other two schemes in terms of energy consumption, outage probability, average throughput, packet loss rate and PSNR.

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