Video Distribution Techniques Over WiMAX Networks for m-Health Applications

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***Abstract*—In this paper, we propose a novel approach for video distribution over IEEE 802.16 networks for mobile Healthcare (m-Health) applications. The technique incorporates resource distribution, scheduling, and content-aware video streaming taking advantage of a flexible quality of service functionality offered by IEEE 802.16/WiMAX technology. The proposed technique is thoroughly investigated using network simulator software under various real-life m-Health scenarios, which include streaming video over medium access control layer service connections. It is shown that the technique is fully compatible with the WiMAX standard specification and allows a 9–16% increase in the overall network throughput, which is dependent upon the initial system configuration and the selection of WiMAX user parameters.**

***Index Terms*—IEEE 802.16/WiMAX, mobile Healthcare (m-Health), MPEG stream, real-time video transmission, scheduling design.**

I. Introduction

IN this paper, we propose a novel approach for video distribution over IEEE 802.16 networks for mobile Healthcare (m-Health) applications. The proposed technique is aimed to operate over existing wireless broadband systems installed in hospitals or any of m-Health dedicated environments. Therefore, there is a need for accommodating the additional m-Health-related traffic over existing networks. The designed technique also allows utilization of the value-added services with intensive bandwidth requirements.

In many examples of m-Health services, local area connections are not sufficient. The IEEE 802.16/WiMAX technology can eliminate these drawbacks by providing broadband connectivity over existing networks for m-Health both fixed and mobile m-Health users in a wireless metropolitan area network environment. Therefore, we select the IEEE 802.16e standard as a baseline specification for our simulations.

Video-based applications are among the most challenging services being offered by the network or service providers. The qualitative range of ultimate set of technical parameters glued to a defined application may still vary from tolerant to stringent depending on an expected service required by a healthcare customer [1]. Streamed video, video on demand, video broadcasting, video surveillance, and online video gaming are based on the same quality of service (QoS) demands for network delivery thanks to the nature of its data content but, nevertheless, have essential differences in jitter, latency or packet-size configuration, and rate constraints. In our research, we focus on the IEEE802.16 standard as one of the emerging candidates for the next generation of International Mobile Telecommunications (IMT)-advanced systems.

This study is based on our previous research [2], [3] that is concerned with the distribution of object-oriented MPEG streams over WiMAX networks with service flows embedded in WiMAX specifications. In this paper, we analyze bandwidth resource allocation depending on a scheduling algorithm and apply splitting of video traffic to evaluate system critical states. Based on the developed software model, we optimize the process of video data segmentation and verify the developed technique through case study scenarios, such as m-Health applications.

In case studies, various QoS-dependant streams were emulated to quantify the achievable improvement in the overall network throughput and identify critical issues that influence the performance. We show that the proposed segmentation of real-time data flows provides both quantitative and qualitative system resources utilization. We also identify possibility for further improvement by developing new approaches for scheduler designs.

The rest of this paper is organized as follows. In Section II, we briefly review the QoS and scheduling techniques embodied in the IEEE 802.16 standard. The developed performance model for segmented medical video data and discussions on advantages and issues of using WiMAX technology for m-Health applications are presented. In Sections III and IV, we describe the developed scheduling algorithm together with simulation parameters and results. Finally, in conclusion, we summarize results and discuss open problems, in Section V.

II. IEEE 802.16 Technology and m-Health Applications

IEEE802.16/ WiMAX has been identified as one of the candidates for the next generation IMT-advanced systems [4], [10]. It is a cost-effective alternative for delivering highly intensive, rate/delay-sensitive traffic generally associated with multimedia applications. With the introduction of IEEE 802.16 m data rates in excess of 75 Mb/s in none-line-of-sight conditions are becoming feasible [4]. The QoS concept incorporated in the standard assumes the ability to manage incoming traffic based on application requirements.

Although the set of functionalities and recommendations specified for QoS support in WiMAX are conceptually

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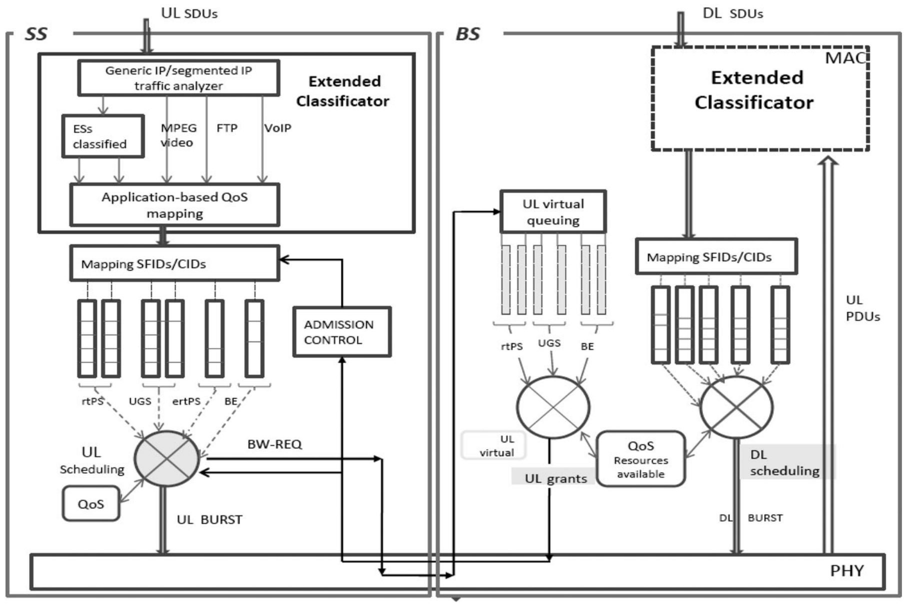

Fig. 1. Novel distribution framework to support object-based MPEG-4 WiMAX video streams.

approved, the scheduling design and explicit structure are left up to vendors and research bodies for further development and implementation [4], [12]–[16]. In the rest of this paper, we explore these areas and apply our results for efficient video distribution over WiMAX networks, ensuring full compatibility with existing and emerging standard specifications.

Users of fixed and mobile m-Health applications can access services via the IEEE 802.16/WiMAX technology. Hence, due to the guaranteed large available bandwidth, it can help us to considerably reduce the transmission delay, e.g., of video and high-resolution ultrasound and radiology images. High bandwidth according to [1], [5], and [6] can as well help us to support various types of m-Health traffic simultaneously and allows the simultaneous transmission of various types of m-Health traffic. IEEE 802.16/WiMAX standard also allows the application of encrypted functionalities via the medium access control (MAC) layers security features for healthcare data transmission.

One of the main issues related to the application of IEEE 802.16BWA (broadband wireless access)-based technology for m-Health applications is *service mapping*. Recently, a number of publications have addressed this issue [5], [7], [8]. Each of the proposed solutions has their own respective advantages and drawbacks. Although there is a room for further optimization of this technique, the following mapping scheme is universally accepted for transferring m-Health data over WiMAX network [8].

1) Allocate unsolicited grant service (UGS) type of QoS to the biosignal traffic and voice conversation.
2) Real-time priority service (rtPS) for the video transmission.
3) Nonreal-time priority service (nrtPS) —to the file transfer, such as x-ray images and ultrasound results.
4) Best effort (BE) service class is to be allocated for the database access, e-mail exchange and web.

In the rest of this paper, we utilize the aforementioned service mapping approach for the efficient m-Health-related video streaming over IEEE 802.16 networks.

III. Distribution Framework and Simulation Model

A novel concept is proposed to utilize object orientation of MPEG video streams for segmented distribution over IEEE 802.16 QoS-supported MAC infrastructure. We utilize a coded representation of media objects [9] where each object is a part of complex audiovisual scene and can be perceived and processed separately. Most video distribution techniques aim at delivering MPEG streams with a defined recommendation for protocol stack exploited within the communication procedures. QoS-supported network transmission technologies provide mechanisms for MPEG video distribution over its infrastructure inherently dictated by the dynamic nature of video traffic. In WiMAX networks service categories rtPS, extended-real-time priority service (ertPS) and nrtPS are used for video-application data delivery depending on QoS needs for a certain video flow. Each elementary steam (ES) belonging to MPEG audiovisual flow can be characterized by stringent QoS requirements that are generally referred to one out of five service categories exploited in WiMAX.

Therefore, MPEG videos can be transmitted through a prespecified MAC service connection of a WiMAX system or, alternatively, many service connections of different service classes can be assigned to incoming MAC Service Data Units (SDUs) of elementary streams segmented from the basic MPEG audiovisual scene.

The *structural framework* of traffic distribution in WiMAX simple topology is illustrated in Fig. 1. In this figure, a base station (BS) is fully responsible for up link (UL) and down link (DL) traffic scheduling. The virtual UL scheduling process is integrated into the BS MAC architecture. The diagram schematically demonstrates data and signaling flows for UL communication between service station and BS. The UL traffic from upper layer of MAC SDUs will be classified on the basis of QoS demands inherently allocated between already existed service connections or put in a buffer for further connection established in line with grant/rejection generated by a BS. In order to set up a new connection identifier (CID), initiated by incoming traffic, the mobile station (MS) utilizes a well-known handshaking procedure to request bandwidth resources from the BS [4]. Due to the increased need of bandwidth in service connections for real time video data, the MS UL scheduler has to either re-allocate the available resources or address the BS for additional provisional QoS setup. As shown in Fig. 1, this request for resources is realized by a Bandwidth Request (BW-REQ) signalling message, outgoing over the WiMAX control channel. When the BS grants the necessary bandwidth, the MS UL scheduler decides whether to delegate this allocation to the maintained CID connection or set up a new one. The scheduling policy and design are beyond the scope of WMAX standard. Equipment vendors are encouraged for proprietary solutions, complied with general standard specifications [4].

Each service connection with packets waiting in the queue has a CID and service flow identifier mapping to deliver packets with certain QoS guarantees to a destination address. The scheduling algorithm plays a major role in assigning burst profiles to awaited packets. It will be reallocating the available resources, implementing a dropping and a connection admission policy, following the distribution function and a mechanism presented in its design.

We extended the functionality of the conventional classifier/analyzer module integrated in WiMAX MAC layer to a number of specific tasks required to support the proposed algorithm. The upper SDUs are analyzed with the purpose of determining IP packets belonging to segmented ESs or generic packets with MPEG payload. Furthermore, those from ESs are to be classified on the basis of QoS needs and then sent to a mapping block to correlate packets with QoS categories offered by WiMAX. Classified ES packets are finally marked as application-based traffic, in the category with similar QoS application needs. After that, the mapping module distributes traffic between unique service connections for supported QoS queues.

A. Description of the Extended Classificator

In order to support the proposed modifications, we introduce *extended classificator* as shown in Fig. 1. The significant value of the integrated *extended classificator* is to simultaneously treat packets from both conventional MPEG-structured and segmented ES video streams to provide freedom to end-users for optional use of either one or another, or both, video transmission schemes. This separation could face a quality difference and be beneficially applied by service operators in commercial implementations.

For the purpose of data identification, we introduce a traffic analyzer module, which is capable of determining incoming

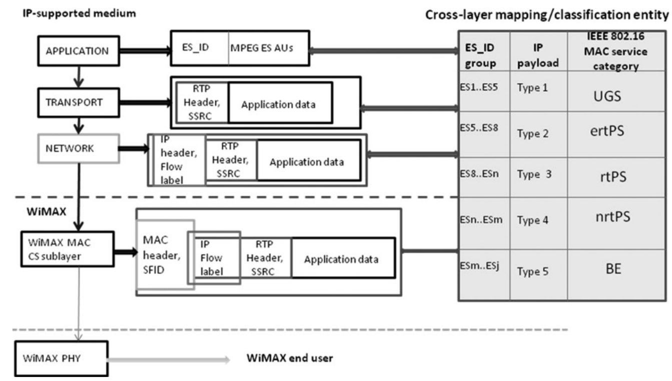

Fig. 2. Modified protocol-based cross-layer architecture.

IP packets. These packets can belong to certain MPEG-generic, MPEG segmented, or conventional application payload types. In this architecture, we add functions, such as handling and identification of MPEG- and MPEG-ES-related traffic. The classification of IP packets from a Hypertext Transfer Protocol (HTTP), voice over IP (VoIP), and other services is specified by the standard. WiMAX MAC convergence sublayer is dedicated to manage the upper layer generated packets, as specified in packet header suppression technology of the IEEE 802.16 standard [4]. The proposed technique is fully compatible with the WiMAX specification and does not require any changes in the standard. The MPEG ES segmentation process is to be performed at upper layers, i.e., IP packets incoming to WiMAX system elements contain signaling information about its segmented parameters and initial audiovisual source.

In our previous research [3], we were focused on mapping ES packets to specific categories of traffic applications, such as MPEG-4 video, as presented in [3]. The mapping rules proposed in this paper introduce modification for WiMAX-enabled cross-layer data forwarding and are shown in Fig. 2. In this diagram, each group of ES refers to a certain application type with the following classification for related IEEE802.16 service classes.

The header of the each layer bears significant information about associated links between ES data and further QoS treatment of incoming packets. We propose a cross-layer entity operating as a mapping/classification table to set up matching rules between communicating layers for delivering packets through the protocol suite. The operating layer is able to classify the incoming SDUs by addressing to cross-layer table. The correct information in the defined header field is inserted to lower layers. However, the design and development of detailed protocol suite for ES–IP packet correlation mechanism and synchronization is beyond the scope of this paper and a topic of further detailed research. Meanwhile, it should be noted that synchronization signaling data should be integrated into the single ES with premium QoS to provide guaranteed resources for delivery, as just the case with UGS service class.

One of the key aspects of video distribution over WiMAX is selecting of the right service class that will not be affected by the performance of the physical (PHY) layer. For example, automatic repeat request of PHY layer dramatically improves the bit error ratio performance in pure (noiseless) channel

TABLE I
TEST PARAMETERS FOR THE FIRST SCENARIO

Service Class	Type M-Health Data to be Transmitted	Packet size, Byte	Data rate, Mbps
UGS	Live Teleconference (video)	200	2
rtPS	Medical Video Transmission (surgery, tutorial, presentation, video consultation)	150	1
Be	Request to the Database	40	0,02

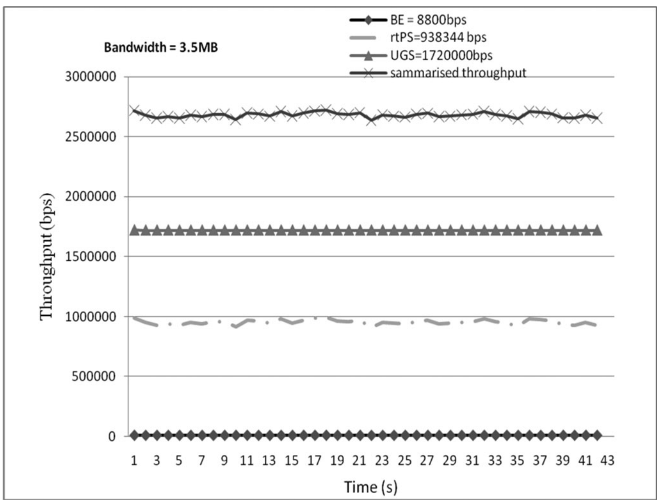

Fig. 3. Throughput comparison for the first (conventional) scenario.

conditions. However, this mechanism introduces delays to the transmission of the video packets [4], [10].

For our study, we have chosen the conventional weighted round robin (WRR) algorithm for UL scheduling and developed a software model on the basis of the proposed program module [11]. The results of this investigation could also be used in the future research related to optimum scheduling design.

IV. SIMULATION SCENARIOS AND EXPERIMENTAL RESULTS

A. Tests of a Novel Segmented Distribution Scheme With the Stress to m-Health Applications

In the developed simulation model, we implemented the direct functional correlation between the ESs and QoS scheduling categories offered in WiMAX. We assume that every ES with its QoS set can refer to a certain IEEE 802.16 MAC connection identified for the related service class UGS, rtPS, nrtPS, etc., which is associated with the specific healthcare application. Thus, this simulation approach means that the ES required for delivery of a data flow generated from a defined object with specific behavior would get appropriate scheduling service as an individual stream with QoS-based application requirements.

In the first scenario, which represents the conventional approach [4], we establish three connections with different service classes, as indicated in Table I. Fig. 3 shows simulation results for the conventional transmission of the first scenario, which is described in Table I.

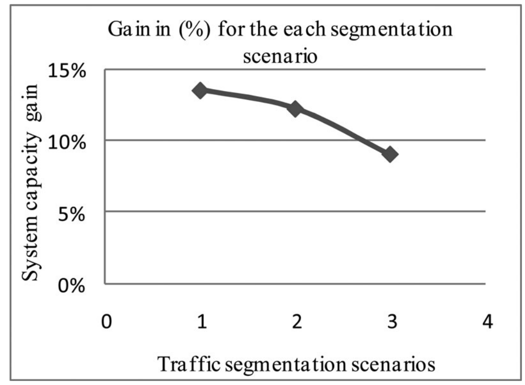

Fig. 4. System bandwidth gain for the second scenario.

Table II presents simulation parameters for the second scenario setup, where the developed technique is applied. The aim of this simulation is not only to test the technique but also to compare its performance over the conventional transmission scenario 1 and demonstrate advantages of the developed technique.

As shown in Table II, both UGS and rtPS streams were split according to the proposed video distribution technique. For example, in scenario 2.1 of Table II, the total UGS load of 2 Mb/s is divided into two UGS streams of 1 Mb/s each. Furthermore, the original 1 Mb/s connection served by rtPS service is divided into two streams. These streams are ertPS and BE with data rates 0.6 Mb/s and 0.4 Mb/s, respectively. In scenarios 2.2 and 2.3 (see Table II), the original UGS traffic rate is unchanged and the BE rate is constant through the whole simulation set.

Fig. 4 shows comparative results in terms of summary throughput gain (system capacity gain), achieved for the second scenario in agreement with the parameters presented in Table II. The percentage gain is calculated based on the comparison of the average summary throughputs of conventional scenario with summary throughput results, obtained for the presented segmentation set scenarios

$$T = \frac{T_{\text{initial}}}{T_{\text{segmented}}}(\%) \tag{1}$$

where T_{initial} is the summarized throughput for the initial video stream; $T_{\text{segmented}}$ is the summarized throughput for segmented scenarios

$$T_{\text{initial}} = \sum_{i=1}^{n} T_i = T_{\text{UGS}} + T_{\text{rtPS}} + T_{\text{BE}} \tag{2}$$

where T_{UGS}, T_{rtPS}, and T_{BE} are throughput results for UGS, rtPS, and BE connections, respectively

$$T_{\text{segmented}} = \sum_{i=1}^{n} \sum_{k=1}^{m} T_{ik} \tag{3}$$

where i is the number of service groups, k is the number of segmented streams within each service group.

As illustrated in Fig. 4, the best gain ratio approximately 14% was obtained when most data are forwarded via connections

TABLE II
SIMULATION PARAMETERS FOR THE SECOND SCENARIO SET

Parameters / Scenario №	UGS1, load, Mbps	UGS2 load, Mbps	ertPS load, Mbps	rtPS load, Mbps	BE1 load, Mbps	BE2 load, Mbps	Summary load, Mbps	Total bandwidth, Mb
№ 2.1	1	1	0,6	0	0,4	0,02	3,02	4
№ 2.2	2	0	0,4	0,5	0,1	0,02	3,02	4
№ 2.3	2	0	0,3	0,5	0,2	0,02	3,02	4

TABLE III
SIMULATION PARAMETERS FOR THIRD SCENARIO SET

Parameters / Scenario N	UGS load, Mbps	rtPS load, Mbps	ertPS load, Mbps	BE1 load, Mbps	BE2 load, Mbps	Summary load, Mbps	Total Bandwidth, Mb
№ 3.1	2	0,5	0,4	0,1	0,02	3,02	3,5
№ 3.2	2	0,25	0,25	0,25	0,02	3,02	3,5
№ 3.3	2	0.1	0,4	0,5	0,02	3,02	3,5

that were served by rtPS and UGS services. In addition, the initial UGS stream of 2 Mbps load was separated in two UGS connections with 1Mbps load per each.

This fact supports our assumption that the segmented approach would lead to better performance in the comparison with traditional IEEE 802.16 MAC delivery. Moreover, as expected, the WRR scheduler first serves packets with a higher priority service connection. Hence, the least successful indications with about 9% capacity gain are provided for the scenario 2.3.

Based on our evaluated results we conclude that two subconnected segmentation models might be a tradeoff solution for delivery video data with two-enchanced quality layers, with rtPS service reserved for m-health video conference transmission. Observing the performance of the described scenario, different video distribution models can be effectively exploited taking into account the scheduling design. Scheduling can evenly improve the performance, as our theoretical concept was experimentally approved with the simple WRR algorithm to which no specific properties were added for a selected service class-oriented priority provision.

The third scenario set is presented in Table III. It is dedicated to study the variation in the overall network throughput when the segmentation scheme is applied. For example, in scenario 3.1, the rtPS stream was separated on every 0.5 Mb/s rtPS, 0,4 ertPS, and 0.1 BE connections; while in scenario 3.2 the same 1 Mb/s rtPS video was simulated as 0.1 Mb/s rtPS, 0.4 ertPS, and 0.5 Mb/s BE separate streams. The throughput for the each connection was analyzed. Results are presented in Fig. 5. As can be seen from this figure, the summarized throughputs for each splitting scheme (see Table III) are compared to the conventional simulation model that is presented in Table I.

This proves our expectation that the variation of the video stream splitting has an impact on the overall system throughput. Knowing this fact, for each type of transmitted video (surgery, tutorial, presentation, video consultation, etc.) it is possible to predict the throughput gain and hence predict the gain for the other type of transmitted data: ertPS (VoIP) or/and BE (web, database access) services, as it was shown for the specific scenario.

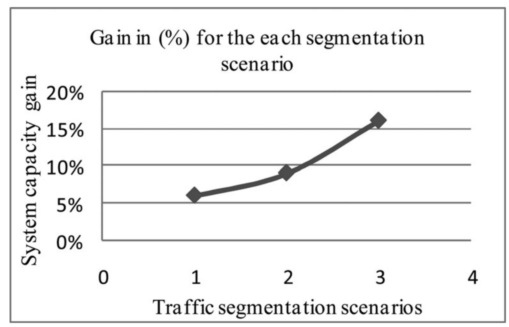

Fig. 5. System bandwidth gain for the third scenario.

Fig. 5 illustrates the gain in percentage among test sets in the third scenario. In this figure, numbers 1, 2, and 3 of the traffic segmentation scenarios indicate scenarios 3.1, 3.2, and 3.3, respectively. The maximum bandwidth gain is obtained in the third set (scenario 3.3) and it is 16% in comparison with the conventional scenario.

In the fourth scenario (see Table IV and Fig. 6), we first assume scenario that the network topology involves two high priority video streams. In addition, one more flow is allocated for data delivery but with less important service requirements, such as nonemergency m-Health applications. Two flows are set with 8 Mb/s data rate and treated as UGS connections with ensured bandwidth allocation. Scenario 4.1 in this simulation set is taken as conventional. A comparison is made with scenarios 4.2 and 4.3 where the proposed technique is applied. The total system load is presented in Table IV. The overall network bandwidth is a constant parameter and well sufficient to effectively manage the incoming traffic for all sets of this scenario.

For the second test (scenario 4.2) with the fourth scenario, we keep the same full system load and bandwidth parameters, but apply our proposed technology and emulate more connections. The UGS connection with 8 Mb/s corresponds to rtPS connections with 4 Mb/s load each referred to three video transmission streams.

Finally, in the 4.3 test, we embrace the same full load segmentation principles, as in the previously described simulation

TABLE IV
SIMULATION PARAMETERS FOR FORTH SCENARIO SET

Parameters / Scenario N	UGS1 load, Mbps	UGS2 load, Mbps	rtPS1 load, Mbps	rtPS2 load, Mbps	rtPS3 load, Mbps	BE1 load, Mbps	BE2 load, Mbps	Summary load, Mbps	Total Bandwidth, Mb
№ 4.1	8	8	4	0	0	0	0	20	28
№ 4.2	8	4	4	4	0	0	0	20	28
№ 4.3	8	0	3	3	3	1,5	1,5	20,2	28

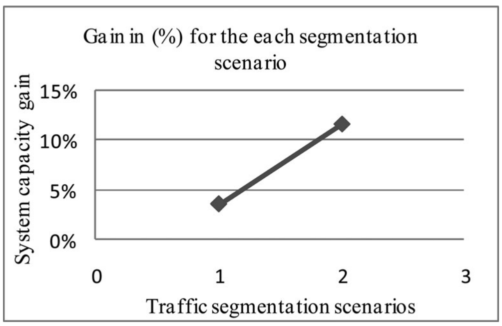

Fig. 6. System bandwidth gain for the fourth scenario.

4.2, but with a reduced traffic flow on rtPS connections down to 3 Mb/s. In addition, the BE connection has 1.5 Mb/s load. The main simulation parameters of the considered tests are provided in Table IV.

It should be noted that the same values of the total system load and system bandwidth are set in all the experiments. All the streams were reallocated among the varied numbers of transport connections of defined QoS classes. This was made to model the variations of quality-selected video streams and to compare the network performance for the considered test scenarios.

The throughput per each connection for the selected aforementioned scenarios with throughput values is analyzed and the bandwidth gain for each connection is presented in Fig. 6.

As can be seen from Fig. 6, the traffic segmentation scenarios 1 and 2 correspond to scenarios 4.2 and 4.3, respectively.

Our feasibility study demonstrates full compatibility with the IEEE 802.16 standard.

V. CONCLUSION

In this paper, we described a novel approach for video distribution over IEEE 802.16 networks for m-Health applications. The technique incorporates resource distribution, scheduling, and content-aware video streaming taking advantage of a flexible QoS functionality offered by IEEE 802.16 technology. The proposed technique was thoroughly investigated under various scenarios, which included streaming video over MAC layer service connections. It is shown that the technique allows 9–16% increase in overall network bandwidth while maintaining full compatibility with IEEE802.16/WiMAX specification. The exact gain is dependent upon initial system configuration and selection of WiMAX user parameters.

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