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Wi-Fi and WiMax QoS Performance Analysis on High-Level-Traffic using OPNET Modeler

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ABSTRACT

Heterogeneous networks continue to be operate thanks to the various services they offer, especially in terms of mobility, wide coverage and rapid deployment. However, quality of service (QoS) is a major challenge for these networks, which often consist of different technologies (WiMAX, WIFI, UMTS, LTE, etc.). This study measures and evaluates the behaviour of Web-based applications in a vertical handover context between 802.16e and 802.11e technologies, taking into account all possible QoS mechanisms. The evaluation scenarios were performed using OPNET Modeler. The applications used are: Dynamic web (HTTP + database) and mail flow. The evaluation criteria used are: TCP delay, HTTP load page delay, DB query delay, mail download and upload delay.

Keywords: 802.16e, 802.11e, HTTP, OPNET Modeler, QoS, Vertical Handover; Web-Based

INTRODUCTION

Digital communication technologies play a major role in connecting users in remote geographical areas. This is often carried out trough heterogeneous wireless networks. Today, information exchanges concern not only email exchanges but also Web-based services, including dynamic web and Web-oriented messaging services (Gmail, Yahoo, Hotmail, etc.). Figure 1 presents the statistics published by EuroStat (http://ec.europa.eu/eurostat/statistics-explained/) and it is clear that companies, through various scales, currently have a tendency to network mobility and are increasingly deploying Web-based applications thanks to their reduced costs, simplicity, ease of use and its multi-platform aspect.

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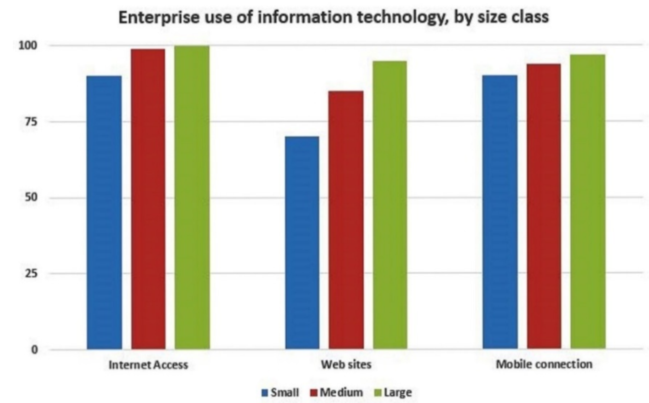

Figure 1. Enterprise use of information technology, by size class. Adapted from "Mobile connection to internet," by EuroStat, 2016 (http://ec.europa.eu/eurostat/statistics-explained/index.php/Mobile_connection_to_internet). In the public domain

Handover

Handover or Handoff in wireless networks is the ability to switch from one access technology to another without losing the connection and having to reconnect (Khiat, Bakkoury, El Khaili, & Bahnasse, 2016).

The Handover types are shown in Figure 2 and listed below:

- Horizontal handover: between two cells managed by the same technology (for example between two WIFI cells).
- Vertical handover: between two cells managed by different technologies (for example between WiMAX and Wi-Fi).

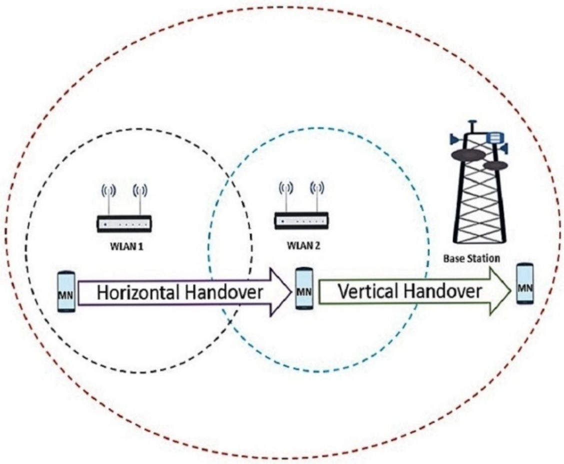

Figure 2. Horizontal and Vertical Handover. From "Study and Evaluation of Vertical and Horizontal Handover's Scalability Using OPNET Modeler," by A. Khiat, J. Bakkoury, M. El Khaili, & A. Bahnasse, 2016, I*nternational Journal of Computer Science and Information Security, 14*(11), p. 807. Copyright 2016 by International Journal of Computer Science and Information Security

IEEE 802.11

WIFI is an international standard describing the wireless LAN characteristics (WLAN). In general, it's the name of the IEEE 80211 standard (Crow, Widjaja, Kim, & Sakai, 1997).

The 802.11b protocol allows a throughput of 11 Mbits to 22 Mbits per second, while the 802.11g protocol allows reaching a theoretical throughput of 54 Mbps.

IEEE 802.11e (Mangold et al., 2002) is an enhanced version of the IEEE802.11 introducing QoS at the MAC layer for the transport of voice, audio and video traffic through the WLAN.

IEEE 802.16

WiMAX means Worldwide Interoperability for Microwave Access. It's a set of technical standards based on the 802.16 (Eklund, Marks, Stanwood, & Wang, 2002) radio transmission standard allowing the transmission of broadband IP data over the air. The maximum theoretical throughput supported by the WiMAXis 70 Mbit / s over a theoretical distance of several tens of kilometres.

In other words, the WiMAX is an alternative solution for the broadband networks deployment in the territories, whether or not covered by other technologies such as ADSL or cable. The WiMAX makes it possible to use both sedentary and nomadic broadband network.

IEEE 802.16e (Choi, Hwang, Kwon, Lim, & Cho, 2005; So-In, Jain, & Tamimi, 2009) this standard was validated in September 2004 and uses the frequency band from 2 to 6 GHz. In practice WiMAX allows a broadband connection while moving at less than 122 km/h. The WIMAX mobile would be a real alternative for transport networks.

Quality of Service

Quality of Service (QoS) is the ability to convey a particular traffic type, in good conditions, in terms of throughput, transmission delays, availability and packet loss rate.
In the heterogeneous networks context (WiFI and WiMAX) the QoS mechanisms implementation is essential, especially since these networks are open access, so a network access management is paramount.

To ensure adequate quality of service in wireless networks, the IEEE 802.11 standard defines two channel access methods:

- Distributed Coordination Function (DCF) (Wu, Cheng, Peng, Long, & Ma, 2002; Bianchi, 2000)
- Point Coordination Function (PCF) (Liu, Zhao, & Zhou, 2011; Oh & Kim, 2005)

The 802.11e standard aims to provide QoS capabilities at the data link layer (HCF Hybrid Coordination Function). Its purpose is to define the different packet needs in terms of bandwidth and transmission delay in order to allow better transmission of voice and video.

In this standard, two new QoS mechanisms are defined:

- EDCA (Enhanced Distribution Channel Access) (Ge, Hou, & Choi, 2007; Tao & Panwar, 2006)
- HCCA (HCF controlled channel access) (Cicconetti, Lenzini, Mingozzi, & Stea, 2005)

The IEEE802.16e WiMAX standard offers four categories for traffic prioritisation:

1. Unsolicited Grant Service (UGS) (So-In, Jain, & Al-Tamimi, 2010)
2. Real time Polling Service (rtPS), (Zhang, Li, Feng, & Wu, 2006)
3. Non-real-time Polling Service (nrtPS) (Ghazal, Mokdad, & Ben-Othman, 2008)
4. Extended real time Polling Service (ertPS) (Abid et al., 2012)
5. Best Effort (BE).

Each of these service classes is intended for specific applications.

- Unsolicited Grant Service (UGS): This service is designed to support services depending on jitter delay or latency such as VoIP (Voice Over IP). It offers a strict guarantee of throughput and latency;
- Real time Polling Service (rtPS): Service supporting variable size data packets. These are usually multimedia streams like MPEG video. It provides guarantees for throughput, but gives a high latency tolerance;
- Non-real-time Polling Service (nrtPS): This service guarantees only the throughput, it's intended for applications that do not depend on the latency time (such as Email);
- Extended real time Polling Service (ertPS): is intended to support real-time data streams characterised by a variable packets size received periodically;
- Best Effort Service (BES): This service gives no guarantee, but offers all possibilities for any application. It's mainly intended for applications like web access.

Table 1
Mapping Service Classes and Applications

Application	Service Class
TI/EI (Over IP)	UGS
VoIP without silence removal	UGS
VoIP with silence removal	ertPS
MPEG	rtPS
FTP	nrtPS
TFTP	nrtPS
HTTP	nrtPS
EMAIL	BE

Note. Adapted from "QoS class mapping over heterogeneous networks using Application Service Map," by M. S. Ryu, H. S. Park, & S. C. Shin, 2006, *Proceedings of International Conference on Networking Systems, and International Conference on Mobile Communications and Learning Technologies*, p. 13. Copyright 2006 by Institute of Electrical and Electronics Engineers

Table 2 presents a comparison between IEEE 802.16e and IEEE 802.11e.

Table 2
IEEE 802.11e vs IEEE 802.16e

	IEEE 802.11e	IEEE 802.16e
Deployment	Short cover (local)	Large cover
Frequency bands	2.4, 2.5 and 5 GHz	Between 2 and 6 GHz
Throughput (theoretical)	Up to 54 Mb/s	Up to 30 Mb/s
Supported mobility type	Low mobility	Low, simple and full mobility
Modulation	OFDM	Scalable OFDMA
QoS Service Classes	Voice	UGS
	Video	rt-PS
	Controlled load	nrt-PS
	Excellent effort	BE
	Best effort	
	Background	

Note. Adapted from Mobius Consulting, Copyright 2007 by Motorola

The rest of the paper is organised as follows: the second section discusses Web-based applications. In the third section, related works to the problem of Web-based applications performance in heterogeneous networks WiFI and WiMAX are presented. An evaluation environment is presented as well discussions on the results obtained in section five while0 the sixth section concludes the paper.

Web-Based Applications

A web application can be manipulated through a web browser. Web messaging, content management systems and wikis are web applications. In the same way as websites, a web application is usually placed on a server and is manipulated by operating widgets using a web browser, via a computer network (Internet, intranet, LAN etc.). Web-based applications belong to the seven layers of the OSI model. However, these applications are transported through the TCP protocol of the OSI model transport layer.

The TCP protocol, considered as reliable, opens a session before data exchange. The session opening, called three-way handshake, allows to reserve the resources between a client entity and the other server.

The TCP protocol, through sequencing mechanisms, can detect retransmission errors and send only lost segments in the network.

This protocol can be evaluated according to the session opening delay and the retransmission number.

Among the main categories of applications deployed in the Web is the dynamic Web (HTTP protocols, Database) and e-mail (SMTP). These two application categories will be discussed.

A dynamic web page is generated on demand, as opposed to a static web page. A dynamic web page content can vary based on information (time, user name, form filled out by the user, etc.). Conversely, the static web page content is in principle identical at each visit.

When a dynamic web page is viewed, an HTTP server sends the request to the software corresponding to this request, and the latter generates and sends the page content.

Figure 3 illustrates an example of dynamic web operation with the flow of requests and responses between systems.

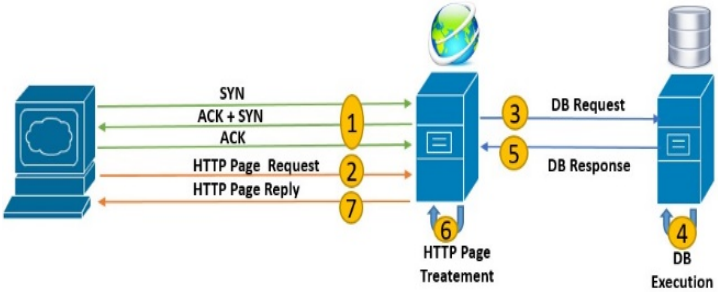

Figure 3. Principle of dynamic web operation

Step 1: The client first opens a TCP session (on three phases) with the Web server.

Step 2: The client prepares the HTTP request to send to the server, this query often contains a parameter, and thanks to it, the page will be built.

Step 3: The Web server logs on to the database server, and returns a request formed by the parameter requested by the user of phase two.

Step 4: The database server executes the query.

Step 5: The database server sends the request result from phase three.

Step 6: The web server generates a new page containing the DB request result.

Step 7: The server delivers the generated page to the client.

Regarding e-mail, SMTP (Simple Mail Transfer Protocol) is the standard protocol for transferring mail from one server to another in point-to-point connection.

It is a protocol operating in connected mode, encapsulated in a TCP/IP frame. The mail is delivered directly to the recipient's mail server. The SMTP works through textual commands sent to the SMTP server (by default on port 25).

Related Works

Grewal and Sharma (2010) studied the enhancement induced by quality of service mechanisms in an 802.16 network, and the authors deployed a variety of applications but did not adopt the nrtps model for Email and FTP applications, which is far from acceptable.

(Qasim (2013, pp. 91-93) compared between different IEEE 802.11 standards, such as b and g, using HTTP traffic. This study was carried out taking into account scalability, but the author did not introduce the DCF and PCF methods, which are currently indispensable for obtaining quality communication.

Musaddiq, Hashmi and Jawed(2013) examined and compared Wireless and Wired technologies without taking into account the quality of service or the applications diversity.

No study has focused on the effectiveness of web-based applications with particular attention to quality of service in a heterogeneous network (“Motorola and Intel”, 2007) in a vertical handover context.

Based on literature review, this study contributes to the body of knowledge by:

- Showing the QoS interest in a vertical Handover;
- Evaluating the different QoS mechanisms in 802.11e and 802.16e networks;
- Taking into account the node mobility;
- Diversifying applications (HTTP, SMTP and database);
- Showing where the QoS is the most influencing.

METHODOLOGY

The study used the OPNET Modeler tool discussed by Lu & Yang (2012, p. 4), and several simulators, such as NS2 discussed by Issariyakul & Hossain (2012, pp. 21-39), NS3 by Riley & Henderson (2010) and OMNET by Varga (2010). The OPNET Modeler is currently considered as one of the best simulators in the wireless networks field (Lucio, Paredes-Farrera, Jammeh, Fleury, & Reed, 2003).

A. The evaluation scenarios

The scenario chosen in the evaluations is shown in Figure 4.

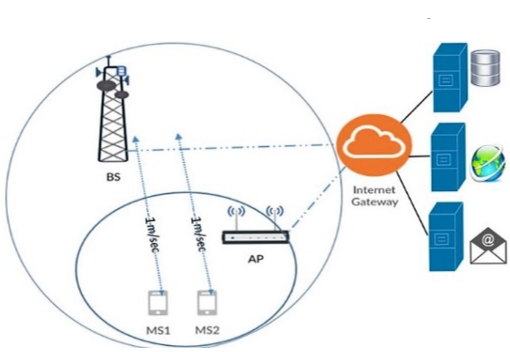

Figure 4. Evaluation simulation model

Based on this model, we have created various scenarios:

- Scenario 1: No QoS on both WiMAX and Wi-Fi.
- Scenario 2: PCF on WiFI, no QoS on WiMAX.
- Scenario 3: HCF EDCA on WiFI, no QoS on WiMAX.
- Scenario 4: No QoS on WiFI, QoS on WiMAX.
- Scenario 5: HCF EDCA on WiFIand QoS on WiMAX.

B. The simulation parameters

The following are the settings used for the WiMAX antenna (Table 3):

Table 3
Base station parameters

Parameter	Value
Antenna Gain	15 dBi
Number of transmitters	SISO
Maximal transmission power	500 mW
PHY profile	OFDM
Maximal power density	-60 dBm
Minimal power density	-110 dBm
The resource retention time	200 msec

The simulation parameters used in Wi-Fi scenarios are listed in Table 4 below:

Table 4
Access point parameters

Parameter	Value
PHY mode	Extended Rate PHY
Throughput	11 Mbps
Transmission power	0.005 W
Beacon interval	0.02 Secs
Buffer size	256 Kilobits

C. Application parameters

Application parameters and evaluation criteria are listed in Tables 5, 6, 7 and 8.

Table 5
HTTP parameters

Parameter	Value
Traffic	HTTP
Object size	10000 bytes
HTTP Specification	1.1
Type of Service	Background

Table 6
DB parameters

Traffic	Database
Object size	32768 bytes
Transaction MIX (Queries/Total Transactions)	100%
Type of Service	Background

Table 7
Email parameters

Parameter	Value
Traffic	Email
Object size	2000 bytes
Send Group Mail	3
Type of Service	Best Effort

Table 8
Evaluation criteria

Criteria	Signification
TCP Delay (Sec)	Delay (in seconds) of packets received by the TCP layers in the complete network, for all connections. It's measured from the time an application data packet is sent from the source TCP layer to the time it's completely received by the TCP layer in the destination node.
TCP Retransmission	Total number of TCP retransmissions in the network. Written when data is retransmitted from the TCP unacknowledged buffer.
Database Response Time (Sec)	Time elapsed between sending a request and receiving the response packet. Measured from the time when the Database Query Application sends a request to the server to the time it receives a response packet. Every response packet sent from a server to an Database Query application is included in this statistic.
HTTP Response Time (Sec)	Specifies time required to retrieve the entire page with all the contained inline (correct?) objects.
SMTP Download Time (Sec)	Time elapsed between sending request for emails and receiving emails from email server in the network. This includes signalling delay for the connection setup.

RESULTS AND DISCUSSIONS

The results are summarised in Figure 5.

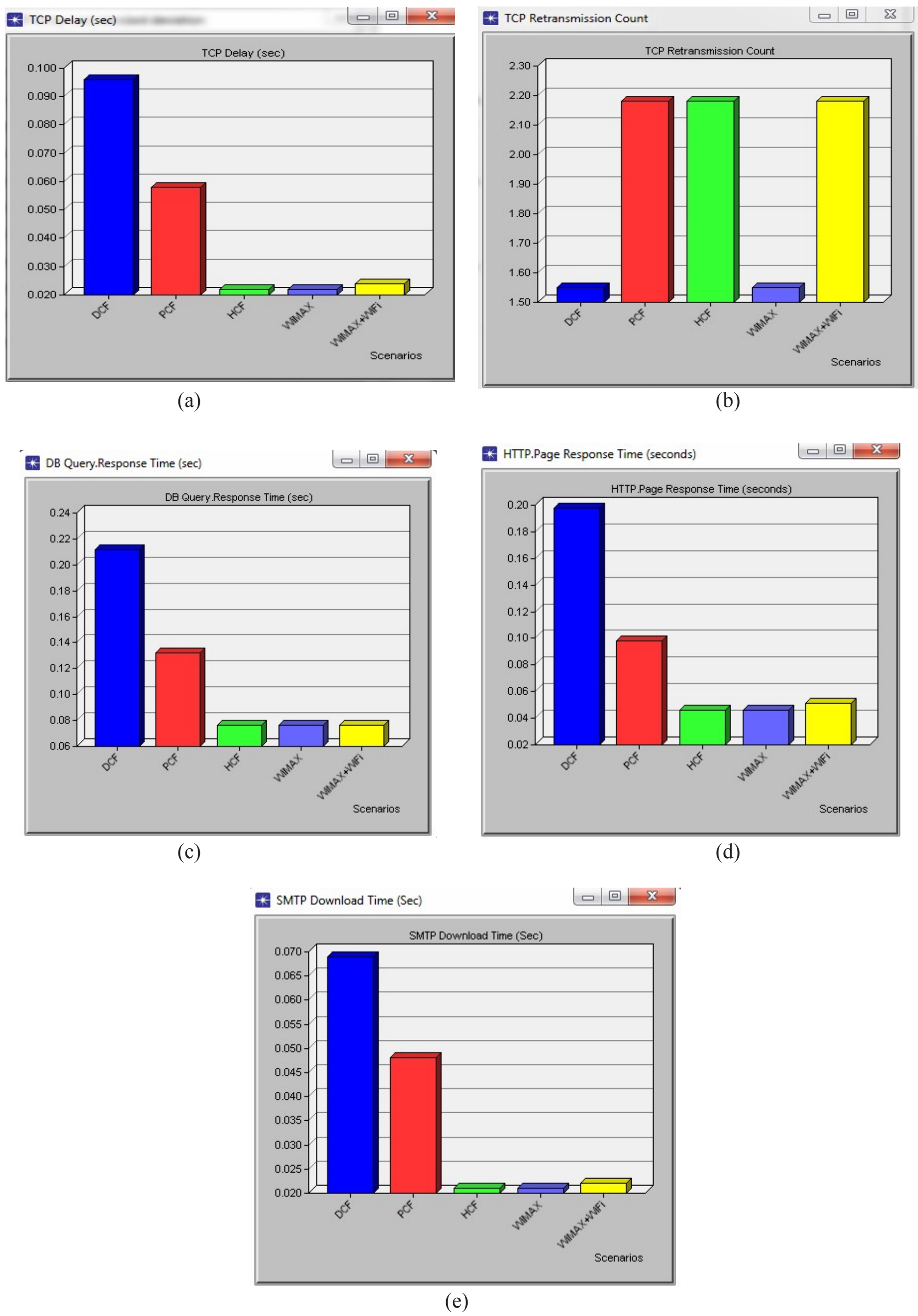

Figure 5. Results achieved (a) TCP Delay (b) TCP Retransmission (c) Database Query Time (d) HTTP Response Time (e) SMTP Download Time

The results from figure (a) and (b) illustrate the opening delay of a TCP session and the retransmissions number. Based on these results, the DCF mode delay is the highest compared with other scenarios, but the retransmissions number is the least. This is due to the fact that in DCF, no classification is guaranteed, so all packets will be treated with the same preference level (Wu et al., 2002).

On the other hand, in the HCF mode, a pre-classification is carried out causing a delay in the BE flow to favour the Background traffic. The waiting time of the BE flow results in its retransmission, and this is clearly noticed by the number of considerable retransmissions in the PCF and HCF scenarios. We remind that the QoS interest is that it reduces processing and transmission delay while seeking the highest reliability (Grewal & Sharma, 2010).

In the WiMAX network, the delay and the retransmissions number are too small given the WiMAX nature (broadband). Concerning the dynamic web flow (c) and (d) we conclude that the HCF mode offers the best results compared with the PCF and DCF modes. This is justified by the fact that PCF uses pooling but does not perform service differentiation in contrast to HCF mode.

From (e) it can be seen that the loading time of a mail remains fixed in all the scenarios PCF, HCF and WiMAX. This can be justified by the fact that the amount of SMTP traffic exchanged is too small compared with the dynamic web flow thanks to the classification process (Figure 6).

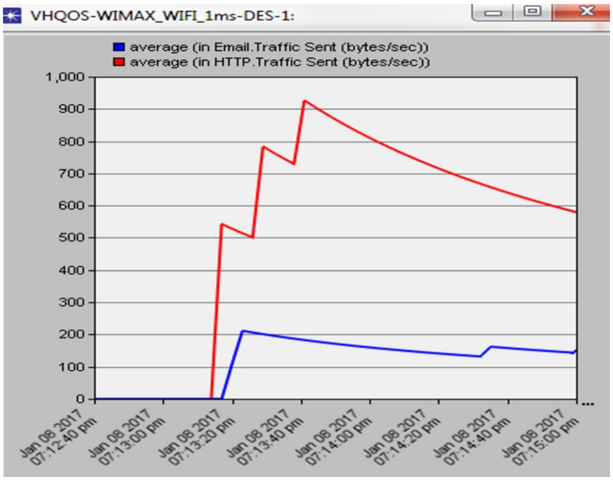

Figure 6. Amount of traffic sent HTTP vs SMTP

CONCLUSION

This paper had studied and evaluated the Web-based applications performance (HTTP, DB, SMTP) in a vertical handover between the two heterogeneous networks (802.16e and 802.11e). It had shown that quality of service is essential when switching from one access technology to another. In addition, the different QoS mechanisms applicable to Web-based applications were studied and the results showed the HCF method efficiency compared with the PCF and DCF in an 802.11e network. However, we found a good network performance when deploying QoS in

802.16e network. Finally, different HCF, PCF and QoS scenarios in WiMAX and Web-based applications offered the same response delays.

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