Sindh Univ. Res. Jour. (Sci. Ser.) Vol. 46 (3) 345-350 (2014)

SINDH UNIVERSITY RESEARCH JOURNAL (SCIENCE SERIES)

Performance Evaluation and Feasibility Report for Coexistence of 2G Infrastructure into 3G cellular Networks in Universal Mobile Telecommunications System (UMTS) as Third Generation Network

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Received 5th March 2014 and Revised 6th July 2014

Abstract: In this paper, the evolution and infrastructure of wireless telecommunication from 2G to 3G, their coexisting portion and the differences between these two technologies in terms of power consumption and data rates are discussed. The up gradation of 2G to 3G is not feasible because of the high cost associated with deployment of 3G. Therefore, 3G is made to coexist with the 2G until the whole the system is transform to 3G. The important aspect of this coexistence is the seamless transition of a user between 2G and 3G networks. The most important part was to make a handover of an active user between these two technologies, especially for a voice call. Simulation was performed in OPNET modeler for soft and hard handover, active set cell addition and cell replacement, power comparison between hard and soft handover, data rate and jitter comparison between 2G and 3G networks.

Keywords: GSM, 2G, 3G, UMTS, FDMA, TDMA.

1. INTRODUCTION

The advancements in the Telecommunication technology and Mobile networking are very rapid from last few years. These networks are separated by a word ”generation” e.g. First Generation (1G), Second Generation (2G) and Third Generation (3G) etc. The reason for differentiating in networks is much difference in technology for each era. At start mobile networks were analogue and with the passage of time technology advances and moved to digital technology.

1st Generation Technology

This generation started in 1980s and continued until 2G.The main difference of 1G from other technologies was that it is analogue while others are digital technologies. At that time there was neither world-wide nor technical standards for development by Europe-wide coordination. Different regions have different standards e.g. NTM used by countries such as Nordic, Switzerland, Netherland and Russia, AMPS used in USA and Australia, TACS in UK, C-450 by West Germany, Portugal and South Africa, Radio com 2000 by France and RTMI by Italy.

2nd Generation Technology

During first generation European Commission started activities towards standardization. Phase one of GSM was published in 1990 and in 1991 first GSM network was launched in Finland. For the first time, data service was also provided for mobile i.e. SMS. GSM provided circuit switching connection. After those two types of standards was introduced TDMA-based and CDMA-based. Main standards include GSM, CDMA One, iDEN and D-AMPS. After that 2G started evolution towards 3G (Holma *et al.*,). 2.5G lies between 2G and 3G. It provides packet switching algorithm. GPRS can be considered as 2.5G and have enhanced data rates. It provides service like multimedia messaging service. GPRS moved towards Enhanced Data rates for GPRS Evolution (EDGE) or EGPRS. Some protocols of EDGE, GSM and CDMA2000 are defined in 3G but can be considered as 2.5G. Before 2nd generation, GSM used an analogue modulation system. It provides us only analogue voice service and it was not able to facilitate any type of data service. These systems faced problems like the size of equipment which was very large and power hungry, it can only deal with very few subscribers due to low capacity of these systems, the system based on analogue technology was not reliable, different countries were adopting different system and they were incompatible to each other and they did not provided worldwide roaming facility. To overcome these problems and getting more reliable and efficient service, we need to introduce another global wireless network. The analogue system was replaced by digital system known as GSM. That has advantages of high capacity, efficient use of radio spectrum, small sized equipment, more coverage and roaming facilities (Kaaranen *et al.*, 2005) **(Fig. 1)**.

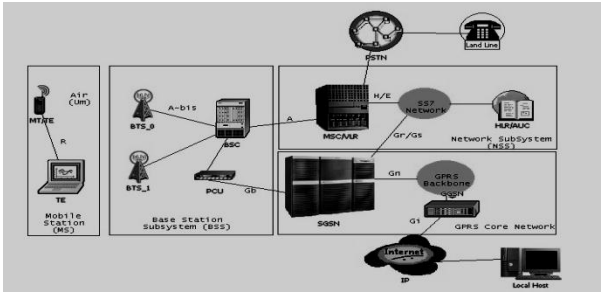


Fig. 1: GSM Architecture

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3rd Generation Technology

3G technologies emphasize on providing better data rates than 2G. It provides features like video call, video telephone, mobile TV, video conferencing and imaging. It also provides greater security. In this technology speech and data rate are propagated simultaneously. The network capacity is increased through improved spectral efficiency (Garg *et al.,* 2001). But still packet transfer act as circuit switch call. The standards included in 3G are GSM EDGE, UMTS CDMA2000 as well as Digital Enhanced Cordless Telecommunications (DECT) and Worldwide Interoperability for Microwave Access (WiMAX). UMTS fall in 3rd generation of wireless networks it introduces new network element and new interfaces to support the high QoS for end users. The architecture of UMTS is divided according to their function. User Equipment (UE), UMTS Terrestrial Radio Access Network (UTRAN) and Core Network (CN). It is necessary to fulfill the specification and standardization of 3rd generation for both UE and UTRAN and they should adopt new protocols. UMTS network can be further divided into sub-network. These sub-systems are able to fulfill the minimum requirement and will provide the entire feature. These sub-systems have their unique identities to distinguish from each other. These sub-systems are connected to each other and other networks like PSTN, ISDN or internet.

4th Generation Technology

4G is the fourth generation of wireless cellular networks. All networks in this generation are IP packet switched. It provides a common platform for all technologies. 3GPP LTE is often named as 4G but it does not fills ITM Advanced (International Mobile Telecommunications Advanced) requirements which requires data rate for higher mobility is *100Mbits/s* and for low mobile is *1Gbits/s*.The RNC and BSC functions are transferred to "4G BTS" (Ebserspacher *et al.,* 2007).

2. MATERIAL AND METHODS CELLULAR NETWORKS HANDOVERS

FDMA and TDMA networks like GSM only supports hard handover while CDMA networks like UMTS introduces two new schemes known as soft handover and softer handover. In hard handover when a MS is supposed to handover to new BS then its connection from the previous BS is disconnected before making a connection to new BS. This type of handover is also referred as "Break-before-Make" handover. This type of handover is applied preferably in FDMA and TDMA networks. The reason behind hard handover is that the adjacent channels use different frequency ranges and by using hard handover system channel interference is minimized. Soft handover occurs when a MS lies in overlapping cell coverage area of two sectors of two different base stations. This scenario can be seen in the **(Fig. 2)**. This is somehow similar to softer handover and both signals are received at MS by maximal ratio combining rake processing. For a MS downlink reception is not much different for a soft and softer handover but for uplink transmission it is different. There are two power control loops per connection, one for each BS. Soft handover occurs in about 20-40% connections.

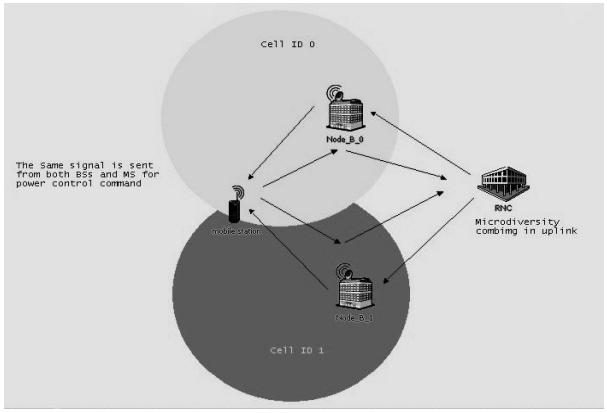


Fig. 2: Soft handover for UMTS

3. MAIN CHALLENGES AND SOLUTION TO COEXISTENCE

The main purpose behind the design of GSM network was efficient and reliable delivery of voice. On the other hand 3G is designed for the best delivery of voice and data. The ultimate goal of 3G is to enhance Data rate and make sure to provide efficient and flexible service with variety of choices. 3G has introduced a new infrastructure but it is not possible to replace the whole infrastructure with 2G at once. It will be expensive for operators because they have some doubts about the reasonable revenue in its initial phase. So that best solution of this problem is the coexistence of both generations. In some areas due to less number of users the deploying of 3G infrastructure is not a good idea in the sense of revenue. There are a number of reasons for coexistence like a large amount of revenue is needed to construct a totally new network like 3G. So it is not possible to uproot the whole 2G network and deploy new 3G network. 3G introduces abundant value added services such as mobile TV, mobile stream media, video phone calls etc. The data of research concluded that 60% of respondent using 3G are satisfy with the service but only 8.5% purchased 3G cell phones. These conditions showed that a large percentage of user still not ready to adopt 3G (Jonathan *et al.,* 2004).

2G and 3G functional elements are connected together with interfaces. These interfaces and elements work together to handle diverse traffic and endow with resource allocation, call processing, billing record, mobility management, radio link management, operation and maintenance functions and gathering of performance statistics etc.

The main challenge is get some realistic and technical solution for MS and network implementations which can make possible to have a successful handover of a voice call from WCDMA system to GSM system and vice versa. Also another challenge is to make as less changes as possible to existing GSM infrastructure. The problems can be overcome by encapsulating the message in "containers". When a handover is needed from WCDMA to GSM, the network sends a WCDMA message which includes a portion of GSM message. And this GSM portion looks exactly as the sender of message is GSM radio interface. This GSM portion is extracted by MS and is processed. Same principle is used when handover is needed from GSM to WCDMA (Alsenmyr *et al.,* 2010). **(Fig. 3)** shows the function of a dual mode mobile terminal. During a handover from GSM to WCDMA, signaling of each relevant parameter is required.

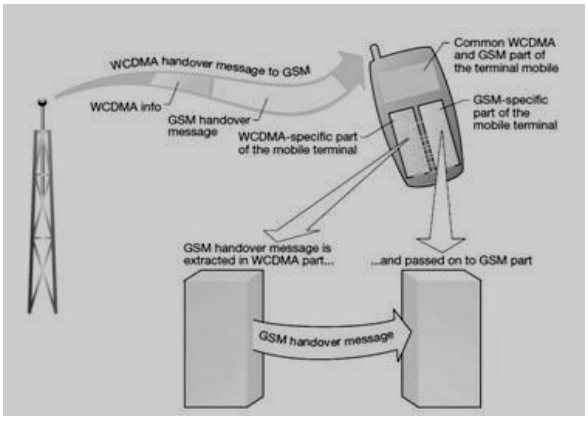


Fig. 3: Dual mode mobile terminals

4. SIMULATION SCENARIOS AND RESULTS

This portion contains the simulations performed on OPNET Modeler. UMTS network supports both soft and hard handover but GPRS only supports hard handover. So when a MS moves within UMTS network we have a choice to make any of the soft or hard handover but for inter-system handover between UMTS and GPRS only hard handover is supported.

4.1 SOFT AND HARD HANDOVER

This simulation **(Fig. 4)** shows the differences between the soft and hard handover in terms of connection of a mobile station to base stations. 3G (UMTS) supports both soft and hard handover but 2G (GPRS) only supports hard handover. First simulation supports soft handover and second does not support soft handover i.e. hard handover.

UMTS and Soft Handover Parameters:
Macro Diversity Threshold: 6.0dB
Macro Diversity Hysteresis: 1.5dB
Replacement Hysteresis: 3.0dB
CPICH Transmission Power: 1.0 Watt
Path Loss Model: Outdoor to indoor and pedestrian environment

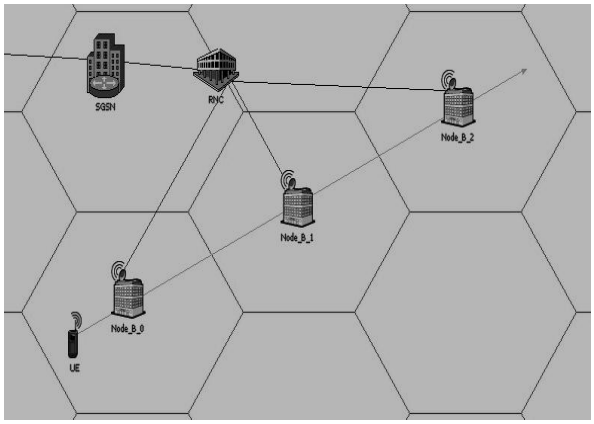


Fig. 4: Handover description scenarios

The simulation results for this scenario are shown in **(Fig. 5 and 6)** these figures are plot of time versus uplink transmission power. X-axis shows time in minutes and Y-axis shows uplink transmission power in dBm. **(Fig. 5)** shows the soft handover while **(Fig. 6)** shows the hard handover procedure.

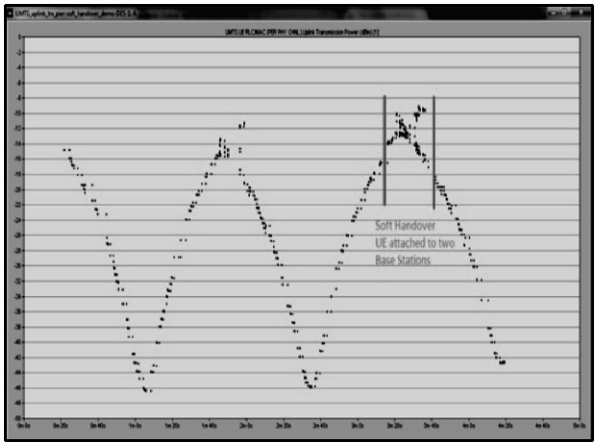


Fig.5: UE attached to two base stations in a soft handover

In (**Fig. 5)** the area between two orange vertical lines is showing the attachment of UE with two base stations. It is clear that after 3 minutes and 20 seconds the UE attaches itself to the new base station. Though it is already attached to first base station but to fulfill

the criterion of soft handover it have to make a new connection before releasing the old one and it kept two connections until 3 minutes and 35 seconds. After that it releases the old connection and only receives data from new connection. During a soft handover as UE is sending and receiving data from two base stations so data rate during this procedure is almost doubled.

Hard handover procedure is shown in **(Fig. 6)** during hard handover the UE is connected to only one base station. As this is a 'break before make' process, so it have to release its old connection before making a new connection. In this figure the area between two vertical lines shows the hard handover of a UE between two base stations.

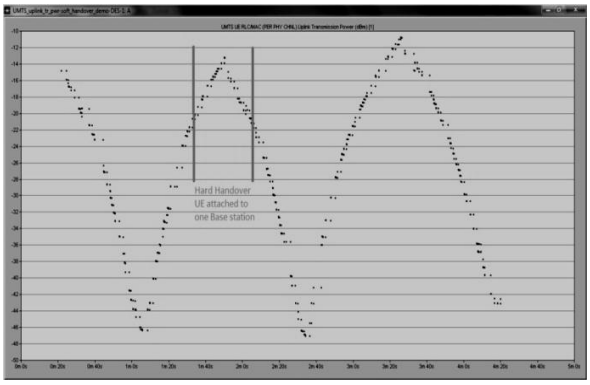


Fig. 6: UE attached to one base station in a hard handover

4.2 POWER COMPARISION BETWEEN SOFT AND HARD HANDOVER

In this simulation the uplink transmission power of a mobile station to check the differences between hard and soft handover in terms of power. Mobile station UE_0 with zigzag trajectory between Node_B_0 and Node_B_1.Total simulation time is 300sec for both types of handovers. The scenario is explained in **(Fig. 7)**. First simulation is performed with supporting soft handover and second simulation is performed with non supporting soft handover. The graphs for the two simulations are compared and analyzed**.**

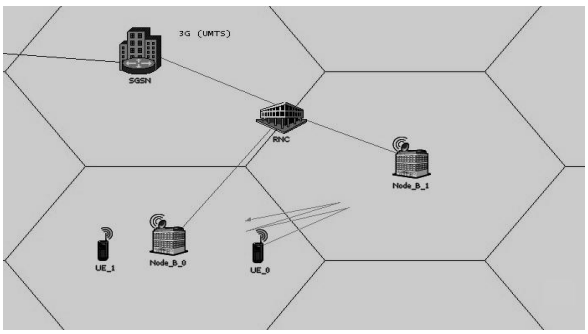


Fig. 7: Zigzag motions within UMTS

The simulation result for this scenario is shown in **(Fig. 8).**X-axis shows time in minutes and Y-axis shows up-link transmission power in dBm. This simulation is performed to analyze the difference between soft and hard handovers in terms of transmission power. Higher power is required when UE moves away from the base station because it needs to maintain its link similarly lesser power is required when it moves towards base station. Hard handover is 'break before make' so it requires more power than soft handover to maintain link. After handover the signal strength becomes good and less power is enough to maintain its QoS. In case of soft handover UE make its connections with two base stations (Node B) simultaneously. When signal strength of current cell goes below the threshold level then it can performs handover with low power to neighbor cell. The uplink transmission power difference is shown in (**Fig. 8)** shows the peak values for up-link transmission power. The transmission power of soft handover is smoother than hard handover. It means soft handover is better than hard handover in terms of low interruption and also needs less power for handover.

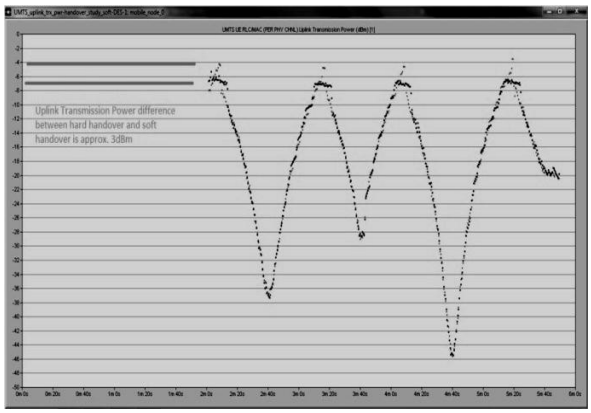


Fig. 8: Uplink transmission power difference between UMTS and GPRS

According to **(Fig. 8)** hard handover uses 3dbm more power than soft handover. Also soft handover is seamless as compare to hard handover and soft handover uses less up-link transmission power, so it is better to improve the capacity of a system and decreases the interfaces.

4.3 DATA RATE COMPARISON BETWEEN 2G AND 3G NETWORKS

One of the main differences between 2G and 3G is the data rates. GPRS can provide a maximum theoretical data rate of 171.2 Kbps and CS-4 can provide 60 - 80 Kbps (depending on time slots) for download whereas UMTS provides at most 2 Mbps. In this simulation we check the data rates when a UE

is in 3G (UMTS) and then in 2G (GPRS). We have selected VoIP service for this scenario because it is able to communicate over VoIP by both UMTS and GPRS networks. The UE_1 is static while UE_0 trajectory is shown in Figure 13. The mobile node UE_0 is a dual mode node which can support both UMTS and GPRS networks. The static node UE_1 is just supporting UMTS network. The VoIP call is initiated after 110 sec. The UE_1 sends data to UE_0 with constant data rate. At 230 sec the UE_0 moves to GPRS cell and at 600 Sec it again comes back to UMTS cell.

The simulation result for this scenario is shown in **(Fig. 9)**. This figure is a plot of time versus average throughput. X-axis shows time in minutes and Y-axis shows average throughput in bytes/sec. Both users are using VoIP service and the results for average throughput are shown. At start UE_0 is connected to UMTS network and it have high data rate resulting high throughput. After that it starts moving away from UMTS base station and after some time when it is handed over to GPRS network the data rate on receiver side decreases. Sender data rate was kept constant throughout the simulation but in real network the sender data rate will also decreases.

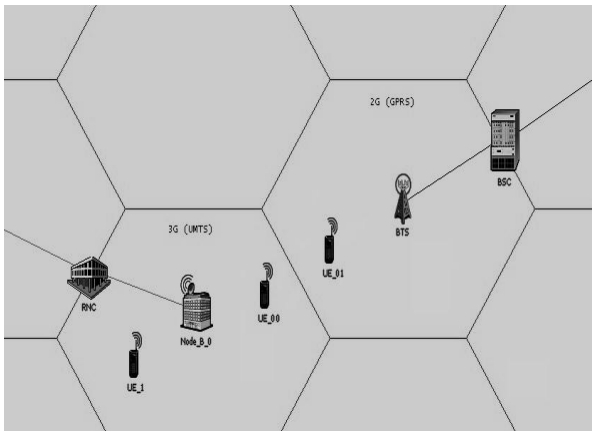


Fig. 9: Inter system handover

If the sender data rate is kept constant in real networks it is possible that a heavy application like video calling is dropped due to high sending rate and low receiving data rate. But here the VoIP call will not drop as we are able to compare data rates between UMTS and GPRS technologies. It is clear from graph that during UE_0 position in 2G coverage area it have to compromise with low data rate and low throughput. When user again come backs in 3G coverage area it again gets high data rate. During this simulation we analyzed that when user moved from 3G to 2G it faced trade off i.e. for gaining high coverage it have to sacrifice data rate. At this point some of these application with high data rate may be dropped or continue with less QoS i.e. web browsing slows down and video call may be dropped **(Fig. 10)**.

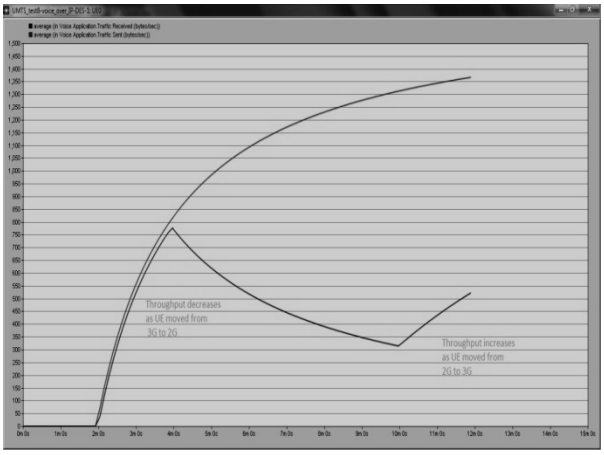


Fig. 10: Data rate comparison UMTS/GPRS

4.4 JITTER COMPARISON BETWEEN 2G AND 3G NETWORKS

The purpose of this simulation is to analyze the jitter of 2G and 3G networks by real time services like VoIP. Jitter is an important parameter to check the QoS of real time application in networks. We made a VoIP call for our simulation because both network can support it. VoIP is working on packet switching technique. In VoIP call data travels in form of number of packets. These packets used different routes to reach their destination and result's in a time difference between each arrival. This variation of time is known as jitter.

The simulation result for this scenario is shown in **(Fig. 11)**. This figure is a plot of time versus average jitter. X-axis shows time in minutes and Y-axis shows jitter in seconds. **(Fig. 11)** shows the jitter in UMTS networks. The average value of jitter varies between 42 and 43 millisecond for whole simulation. These values of jitter are good to make a high quality VoIP call.

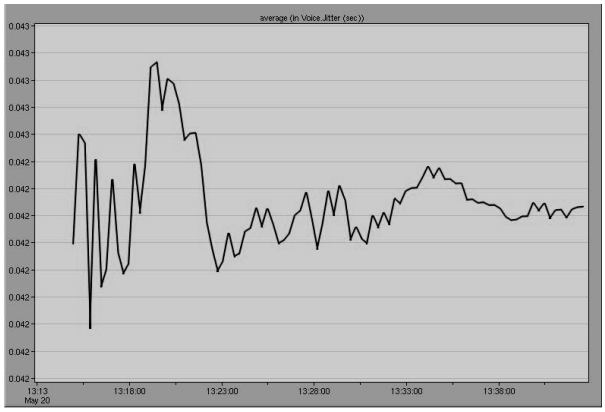


Fig. 11: Jitter for UMTS

The jitter results for GPRS network is shown in **(Fig. 12)**. Voice transmissions are a real service and have some requirements for QoS. It has acceptable transmission delay of 200ms and in some circumstances up till 400ms (Bellalta *et al.*, 2002). The average value for jitter in our case is 300 milliseconds, though it is higher than UMTS network but according to (Bellalta *et al.,* 2002) this is acceptable to make VoIP call.



Fig. 12: Jitter for GPRS

Jitter is proportional to traffic load. It is clear with same traffic load that QoS of UMTS network is much better than 2G because high data rate is vital difference between these two technologies. Results showed that there is a large difference between the values of jitter for both networks. UMTS network has more bandwidth and have less congestion because it provides more capacity as compare to GPRS so it can provide better QoS in terms of real time traffic.

5. CONCLUSION

This paper provides a thorough analysis of 2G and 3G technologies. The handover scenarios between UMTS and GPRS networks in OPNET Modeler are also discussed. The main reason of introducing the 3G technology was the better data rates than existing technology so a comparison was needed in term of data rate. A comparison between 2G and 3G networks in terms of data rates, throughput and jitter has been made. The simulations reveals that 3G have a higher data rates as compared to 2G and thus, support more advanced features like video conferencing and online streaming.

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