WIRELESS TERRESTRIAL COMMUNICATIONS: CELLULAR TELEPHONY

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Contents

Summary

Cellular telephony encompasses the use of cellular phones to place voice calls, exchange short messages, transmit data, browse the web, and issue multimedia calls. In this topic we describe the evolution of cellular telephony mobile networks, mobile terminal features, and elaborate on the associated cellular services and underlying supporting technologies.

1. Introduction

A wireless mobile communication network enables users equipped with mobile terminals to initiate and receive phone calls. This capability is referred to as cellular telephony. In the following we describe mobile networks and the mobile terminals used by mobile subscribers to carry out cellular calls. We proceed with an account of the history of cellular telephony and elaborate on the evolution of networks and subscriber services, including the convergence of data networks towards the wired Internet standards.

Cellular telephony has evolved to include many services that are based on the transmission of data and multimedia, not just voice. Mobile subscriber services offered by cellular operators are described next. The underlying technologies of some services are detailed as well. Finally, we end with a description of cellular telephony quality-of-service and explain how cellular operators bill for user services.

2. Mobile Networks

Cellular telephony derives its name from the partition of a geographic area into small "cells". Each cell is covered by a local radio transmitter and receiver just powerful enough to enable connectivity with cellular phones, referred to also as mobile terminals, within its area (Figure 1). The set of cells forms the radio access network, and the radio frequencies used for the transmission of calls and data can be reused between cells. A different type of reuse, digital code reuse, is used in CDMA-based networks described later on. Voice and data exchanged between a mobile terminal and regular phone networks, or the Internet, are transmitted via the mobile network which consists of the cellular operator's radio access network and core network.

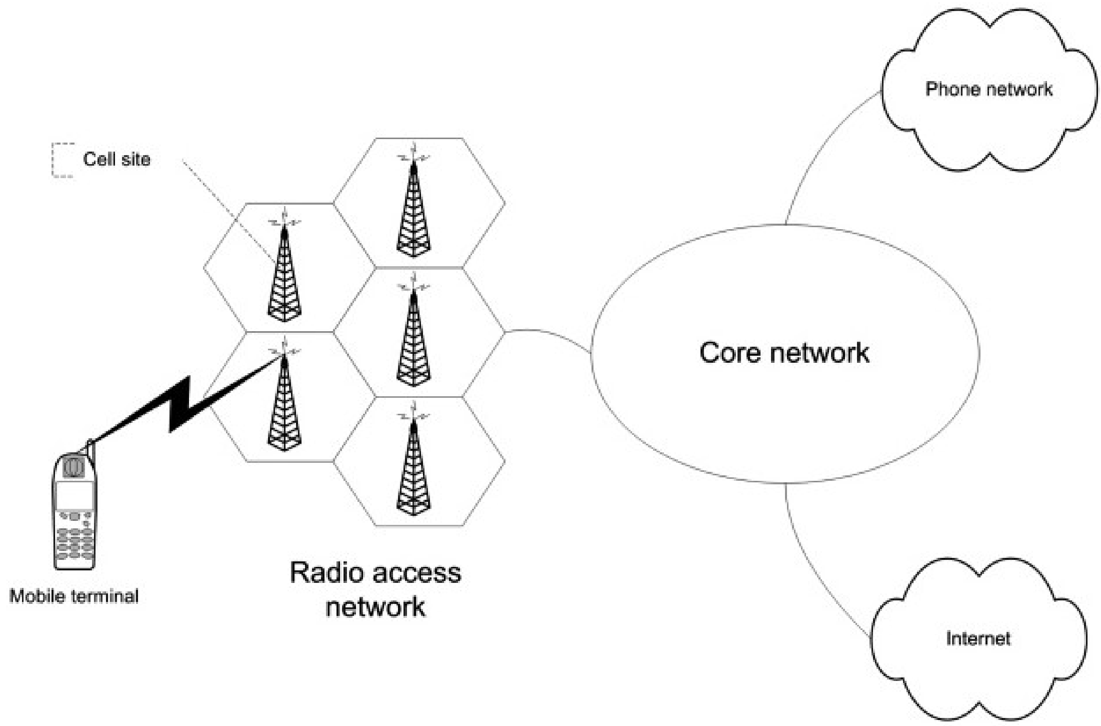

Figure 1: Mobile network

2.1. Cell Sites

A cell site is a site where antennas and radio transmitters and receivers are placed to create a radio coverage area in the mobile network. Cell sites can be omni-sector, meaning that the same frequencies are used in all directions, 3-sector where the site coverage is partitioned into three distinct directional areas, each referred to as a cell (Figure 2), or 6-sector if the partition is into six areas, in which case the site consists of six cells. A separate radio frequency is used for each direction of the communication between mobile terminal and cell site. Communication from the mobile terminal to the cell site is referred to as uplink transmission, and the reverse direction is the downlink.

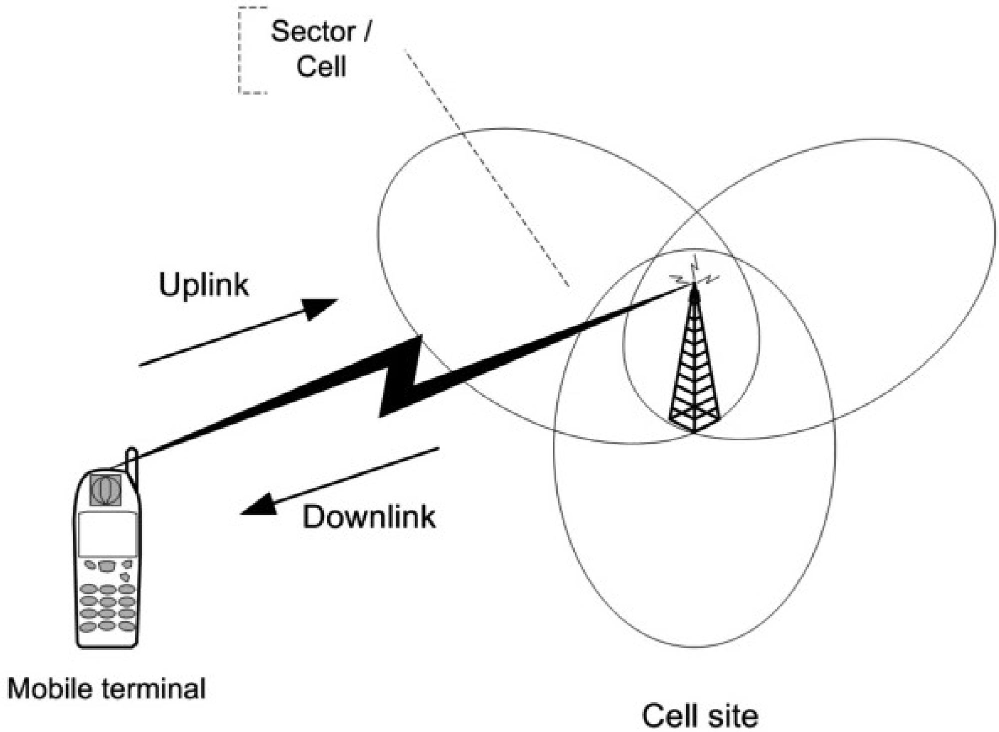

Figure 2: 3-sector cell site

The spectrum of radio frequencies available for communication is limited and a benefit of a mobile network is its ability to reuse radio frequencies in different cells, provided that radio interference does not affect the calls. This reuse provides for increased network capacity as more mobile subscribers can be supported in a given geographic area. As the number of mobile subscribers increases, more cells can be added or existing cells can be split into smaller ones. Two major factors that impact interference are the distance between cells and the cells' transmission power. The layout of cells, allocation of frequencies, and transmission power specifications are part of radio frequency (RF) planning carried out by the cellular operators.

2.2. Mobile RF Spectrum

Radio frequencies are allocated to different cellular radio technologies as shown in the map of Figure 3 and associated tables (Table 1- Table 6). Only a few countries are listed as examples of the spectrum allocation.

Figure 3: Radio frequencies allocation; (Source: www.ctia.org)

Country	**Cellular Radio Technologies (Frequency - MHz)**
Austria	GSM-900/1800, W-CDMA
Belgium	GSM-900/1800
Finland	GSM-900/1800
France	GSM-900/1800
Germany	GSM-900/1800
Greece	GSM-900/1800
Italy	GSM-900/1800, W-CDMA, TACS-800
Russia	GSM-900/1800, CDMA-450/800, TDMA-800, AMPS-800, NMT-450
Spain	GSM-900/1800, TACS-800
United Kingdom	GSM-900/1800

Table 1: ITU region 1 (light blue)

Country	**Cellular Radio Technologies (Frequency - MHz)**
Iran	GSM-900
Iraq	GSM-900
Israel	GSM-900, CDMA-800, TDMA-800, iDEN-800, AMPS-800
Jordan	GSM-900
Kazakhstan	GSM-900, CDMA-800, AMPS-800
Saudi Arabia	GSM-900

Syria	GSM-900/1800
Turkey	GSM-900/1800, NMT-450
UAE	GSM-900, W-CDMA
Uzbekistan	GSM-900/1800, CDMA-800, TDMA-800

Table 2: ITU region 1 (red)

Country	**Cellular Radio Technologies (Frequency - MHz)**
Algeria	GSM-900
Côte d'Ivoire	GSM-900/1800
Democratic Republic of Congo (ex-Zaire)	GSM-900/1800, CDMA-800, AMPS-800
Egypt	GSM-900
Ethiopia	GSM-900
Ghana	GSM-900, TACS-800, AMPS-800
Kenya	GSM-900
Nigeria	GSM-900/1800, TACS-800
Senegal	GSM-900/1800
South Africa	GSM-900/1800

Table 3: ITU region 1 (brown)

Country	**Cellular Radio Technologies (Frequency - MHz)**
Canada	GSM-1900, CDMA-800/1900,TDMA-800/1900, iDEN-800, AMPS-800
Mexico	GSM-900/1800
USA	GSM-900/1800

Table 4: ITU region 2 (dark blue)

Country	**Cellular Radio Technologies (Frequency - MHz)**
Argentina	GSM-1900, CDMA 800/1900, TDMA-1900/800, iDEN-800, AMPS-800
Brazil	GSM-1800, CDMA-800, TDMA-800, iDEN-800, AMPS-800
Chile	GSM-1900, CDMA-1900, TDMA-800, AMPS-800
Colombia	GSM-800/1900, CDMA-800, TDMA-800, AMPS-800
Costa Rica	GSM-1800, TDMA-800
Ecuador	GSM-800, TDMA-800, AMPS-800
Paraguay	GSM-1900, TDMA-800/1900, AMPS-800
Peru	GSM-1900, TDMA-800/1900, AMPS-800
Puerto Rico	GSM-800/1900, CDMA-1900, TDMA-800/1900, AMPS-800

Table 5: ITU region 2 (green)

Country	**Cellular Radio Technologies (Frequency - MHz)**
China	GSM-900/1800/1900, CDMA-800
China – Hong Kong	GSM-900/1800, CDMA-800, W-CDMA, TDMA-800
India	GSM-900/1800, CDMA-800
Indonesia	GSM-900/1800, AMPS-800, CDMA-800
Japan	CDMA-800, PDC-800, AMPS-800
Korea	GSM-900, CDMA-800/1700
Malaysia	GSM-900/1800, TDMA-800, TACS-800, NMT-450
Nepal	GSM-900
Pakistan	GSM-900, TDMA-800, AMPS-800
Philippines	GSM-900/1800, AMPS-800, iDEN-800
Singapore	GSM-900/1800
Taiwan	GSM-900/1800, CDMA-800
Thailand	GSM-900/1800/1900, CDMA-800, AMPS-800

Table 6: ITU region 3 (yellow)

2.3. Subscriber Mobility

Cellular telephony is different from landline telephony in that the mobile subscriber can place and receive calls while on the move without any disruptions in the calls. When a mobile subscriber travels during a call, the network will maintain the call so that it proceeds uninterrupted by handing it off between cells in the mobile subscriber's path (Figure 4).

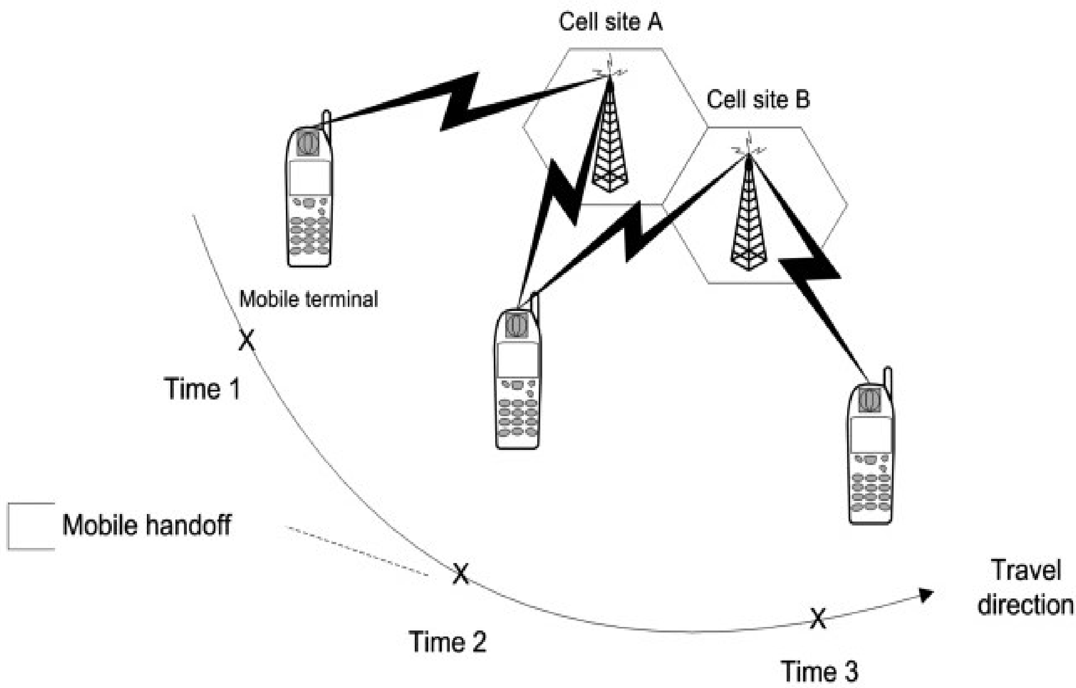

Figure 4: Mobile terminal handoff

Since adjacent cells use different radio frequencies, the mobile terminal moves from one radio frequency to another in the process of being handed off. The design of a cellular system needs to verify that handoffs are fast so that roaming subscribers don't experience any noticeable break in their calls.

To receive a call, a roaming subscriber needs first to be located. To support subscriber location tracking, a cellular network is partitioned into location areas (Figure 5). Each location area consists of a number of adjacent cells and whenever a subscriber moves from one location area to another, a location update indication is sent to the mobile network. The network tracks the current location area for each subscriber so that when there is an incoming call, the network pages all the cells in the current location area. After the mobile terminal responds to the page with an indication of the current serving cell, the call can be routed to the right cell and the mobile terminal alerts the mobile subscriber through ringing that there is a pending call.

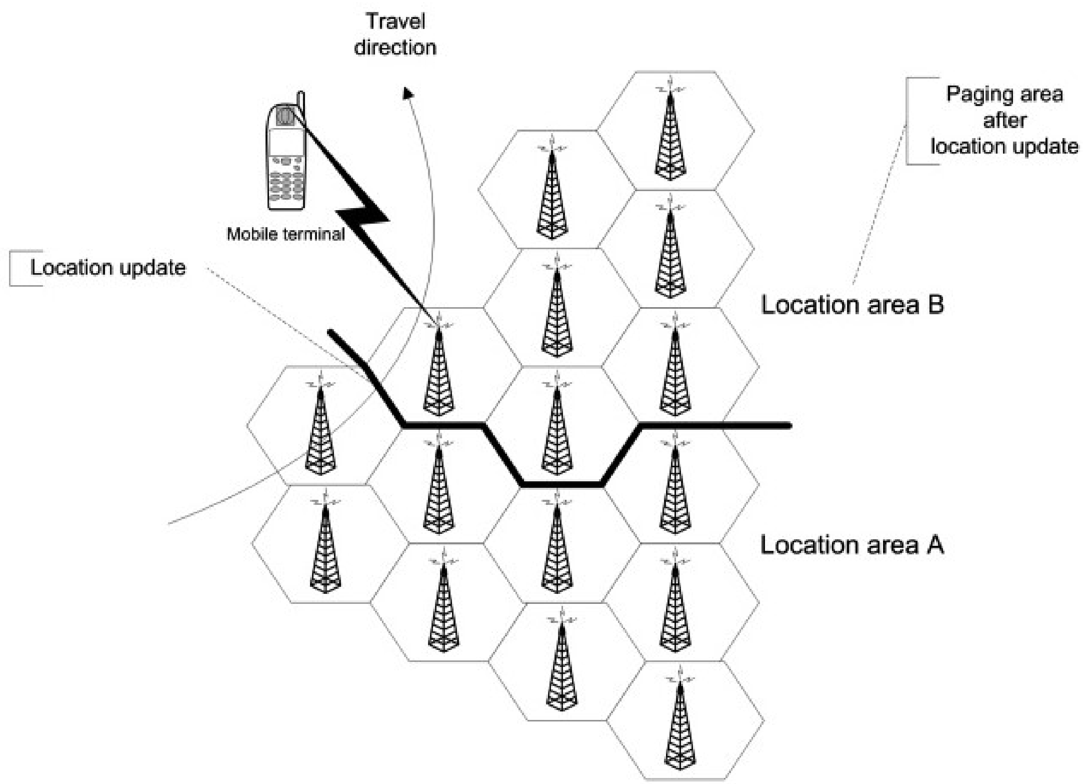

Figure 5: Location areas for mobile paging

The partition of a cellular network into separate location areas and the corresponding location updates issued by the mobile terminal ensure that subscriber location is an efficient procedure. The alternative, if there are no location areas, is to page the whole network, which could span the whole of a country, whenever there is an incoming call. This would obviously place too high an overhead on a network's communication channels. The smaller the size of location areas, the higher the number of location updates issued by roaming subscribers. Effective sizing of a network's location areas ensures that the number of location updates does not negatively impact the network's communication capacities.

3. Mobile Terminals

Today's mobile terminals provide relatively large color screens. Some have touch-sensitive color screens with a stylus used for selections and text input. Besides a radio for cellular telephony, supported local connectivity often includes infrared, USB, and Bluetooth. Many phones include an embedded digital camera, a video player, and some include an MP3 player.

The internal memory can reach tens of megabytes, and an external memory card is sometimes available too. Java development and run-time environments are often provided so that a large number of applications are made available through the Java development community. Speaker dependent voice commands are enabled in many phones, allowing for hands free operation. Included micro-browsers support a number of markup languages, often including the latest release of the HTML language, HTML 4.01.

An example cellular phone is shown in Figure 6.

Figure 6: Sony Ericsson P910; (Source: © Sony Ericsson 2006. All right reserved)

This particular phone model, the Sony Ericsson P910, has a relatively large screen and a number keypad that can be flipped open to reveal on the back a QWERTY-style keyboard for entering text messages.

GSM and UMTS mobile terminals are required to have a subscriber identity module (SIM) card. A SIM is a small form smart card which stores mobile subscriber identifying information, subscription information, preferences, and contacts information. By moving a SIM card from one mobile terminal to another, a mobile subscriber can use this latter terminal and be charged for the calls that are placed on it. The SIM also stores the current location area identity to help the mobile terminal determine if it needs to send a location update message when it is turned on

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Bibliography

3GPP, http://www.3gpp.org [the Third Generation Partnership Project (3GPP) is a collaboration of telecommunications standards bodies to produce globally applicable Technical Specifications and Technical Reports for a 3rd Generation Mobile System based on evolved GSM core networks and the radio access technologies that they support]

3GPP TS 03.60, "General Packet Radio Service (GPRS); Service description; Stage 2". [defines the stage-2 service description for a General Packet Radio Service (GPRS), a packet-mode technique to transfer data on GSM]

3GPP TS 22.228, "Service requirements for the IP multimedia core network subsystem". [this specification defines the service requirements from users' and operators' perspective for the support of IP multimedia applications such as speech communication, real time multimedia applications, shared online whiteboards, etc.]

3GPP TS 23.002, "Technical Specification Group Services and Systems Aspects; Network architecture". [presents the possible architectures of the Universal Mobile Telecommuncation System (UMTS)]

3GPP TS 23.040, "Technical realization of the Short Message Service (SMS)". [describes the Short Message Service (SMS) for GSM/UMTS networks]

3GPP TS 23.207, "End-to-end QoS concept and architecture". [provides the framework for end-to-end Quality of Service involving GPRS and includes aspects of interworking to the IM subsystem as well as PSTN and other networks]

3GPP TS 23.228, "IP multimedia subsystem; Stage 2". [defines the stage-2 service description for the IP Multimedia Core Network Subsystem (IMS), which includes the elements necessary to support IP Multimedia (IM) services]

3GPP TR 23.804, "Support of SMS and MMS over generic 3GPP IP access". [investigates solutions for providing 3GPP messaging services across WLAN, and, more generically across any form of IP access that is part of the 3GPP system]

3GPP TS 31.102, "Universal Subscriber Identity Module (USIM) application". [defines the Universal Subscriber Identity Module (USIM) application. This application resides on an integrated circuit card]

3GPP2, http://www.3gpp2.org [the Third Generation Partnership Project 2 (3GPP2) is a collaborative third generation (3G) telecommunications specifications-setting project comprising North American and Asian interests developing global specifications for ANSI/TIA/EIA-41 Cellular Radio Telecommunication]

3GPP2, S.R0005-B v1.0, "Network Reference Model for cdma2000 Spread Spectrum Systems". [recommends the basic 3GPP2 Wireless Network Reference Model of network entities and associated reference points]

3GPP2, S.R0079-A, "Support for end-to-end QoS". [describes the requirements necessary to support end-to-end quality-of-service (QoS) in the cdma2000 wireless IP network by leveraging, and extending where applicable, the standard IETF protocols for QoS]

C. Anderson, (2001) "GPRS and 3G wireless applications", John Wiley. [describes the GPRS and 3G cellular networks and the development of applications for these networks]

A. Pashtan, (2005) "Mobile web services", Cambridge University Press [describes the key network elements, software components, and software protocols that are needed to realize mobile Web services, including the concept of user context and its potential to create personalized services]

CDG: The CDMA Development Group, http://cdg.org [the CDMA Development Group (CDG) is an international consortium of companies who have joined together to lead the adoption and evolution of 3G CDMA wireless systems]

IETF RFC 2002, "IP Mobility Support". [specifies protocol enhancements that allow transparent routing of IP datagrams to mobile nodes in the Internet]

IETF RFC 3261, "SIP: Session Initiation Protocol". [describes SIP, an application-layer control protocol for creating, modifying, and terminating sessions with one or more participants for Internet telephone calls, multimedia distribution, multimedia conferences, etc.]

International Engineering Consortium (http://www.iec.org), "Billing in a 3G environment" [examines the challenges that service providers face in deploying billing systems that support the evolution from 2G to 3G cellular services]

M. Mouly & M.B. Pautet, (1992) "The GSM system for mobile communications", Mouly and Pautet. [describes the GSM standard for mobile stations, switching equipment, radio interface, transmission methods, and signaling protocols]

Open mobile alliance, http://www.openmobilealliance.org/ [the Open Mobile Alliance (OMA) is an industry forum to facilitate global user adoption of mobile data services by specifying market driven mobile service enablers that ensure service interoperability]

M. Pipikakis, (2004) "Evaluating and improving the quality of service of second generation cellular systems", Bechtel Telecommunications Technical Journal, v.2, n.2. [describes network performance management and quality of service (QoS) of matured second generation (2G) cellular systems]

R. Koodli & M. Puuskari, (2001) "Supporting Packet-Data QoS in Next-Generation Cellular Networks", IEEE Communications, Feb. 2001 (http://www.comsoc.org/ci1/private/2001/feb/koodli.html) [describes the packet data quality-of-service (QoS) architecture and specific mechanisms that are being defined for multi-service QoS provisioning in the Universal Mobile Telecommunication Systems (UMTS)]

Biographical sketch

Ariel Pashtan, Ph.D., is President of Aware Networks, Inc., Illinois, USA (http://awarenetworks.com). He develops wireless web applications, writes, and consults on cellular services. Ariel has over 20 years of industry experience working for Motorola, IBM, Gould, and Israel Aircraft Industries. He was a distinguished member of the technical staff in Motorola Labs where he managed research projects. His past experience includes leading wireless Web services architecture research, and cellular network management requirements and standards teams. Past academic appointments include teaching at

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