

# Analysis of Wireless Data Transmission over GSM Short Message Service (GSM-SMS)

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## Abstract:

*Over the last few years, the GSM cellular phone has grown from a luxury item owned by the rich to something so common that one out of five humans already owns one. This continuously growing popularity of the GSM cell phone has spurred the growth of the country's cellular network infrastructure. All major urban areas are currently covered by different cellular providers, and soon every single corner of the world is a cell phone call away. The text boom has not come unnoticed to entrepreneurs. A variety of services have grown around "Texting." Users will pay double or quadruple the normal SMS fee for a specific service such as chatting, news/traffic reports, and downloading of ring tones for their phones. These services ally themselves with one or more cellular network providers who will give them a special phone number that can receive and monitor the text messages that their customers send to them. This many-to-one network of SMS transmission has become quite popular and many a business has entered into this model with mixed results. However, as of this writing, the vast majority of businesses that revolve around the GSM-SMS system have been targeted to consumers. This paper aims to understand SMS technology that will utilize the distinct advantages of the GSM-SMS system over other possible technologies.*

## Future Growth of GSM-SMS Technology:

SMS messages are an alternative to voice communication over the telephone when silent, private, or very brief communications are best. Since they are somewhat non-traditional, SMS messages have an element of playfulness that often encourages creativity, and customers can find such novelty addictive. SMS messages can be sent between users or to and from an application, which gives service development an extra flexibility that encourages innovation.

Here are some of the ground rules for SMS set down in the Global System for Mobile

Communications (GSM) standard:

**Length and type** — each message can contain up to 160 alphanumeric characters.

Some non-text-based formats, such as binary, are also supported for specialized uses such as ring tones and images.

**Storage and forwarding** — Messages can be stored and forwarded because they are not sent directly from sender to receiver, but pass through an SMS message center.

**Confirmation** — Message delivery is always confirmed, whether the message is delivered or not.

**Simultaneous traffic** — Because the mechanism for transmitting SMS messages is part of the SS7 control channel, which is separate from the voice path of any particular call, short messages can be sent and received at the same time as voice, data, and fax calls. For this reason, SMS users usually do not receive busy signals.

**Increased length** — Methods for concatenating several short messages and compressing messages are defined and incorporated in the standard.

North America Mobile penetration rates in North America are currently about 15 percent lower than in Europe, but are expected to slightly exceed European and Japanese levels by 2006. See Table [iGillottResearch] for current and predicted mobile penetration rates in North America.

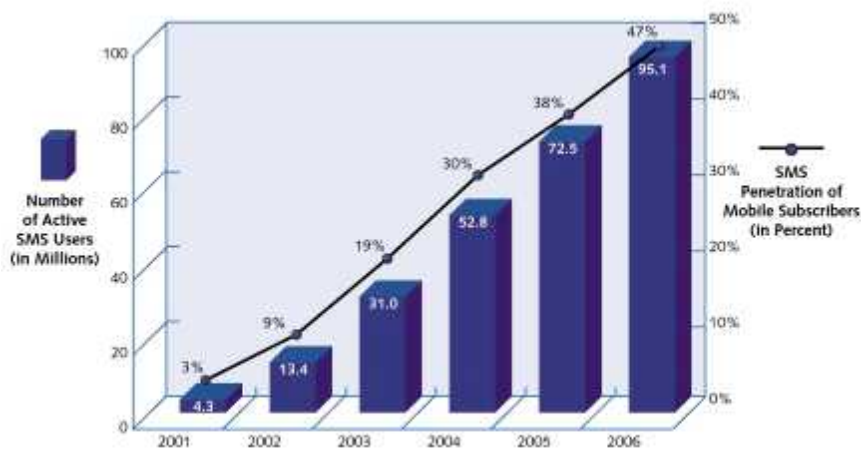
(000s) CAGR	2001	2002	2003	2004	2005	2006
Total Subscribers 13.2%	134,800	153,200	174,200	199,900	224,000	250,800
Population	311,000	313,022	315,213	317,419	319,641	321,879
Penetration Rate	43.3%	48.9%	55.3%	63.0%	70.1%	77.9%

Cellular Penetration Rates in North America

SMS usage has also lagged behind Europe and Japan, but industry analysts anticipate that it will catch up quickly. Active SMS users are expected to rise sharply from 9 percent in 2002 to 47 percent in 2006.

### Active SMS Users in the United States

Source: the Yankee Group, 2002



Active and Projected Users in United States

### Basic GSM Terminology and SMS:

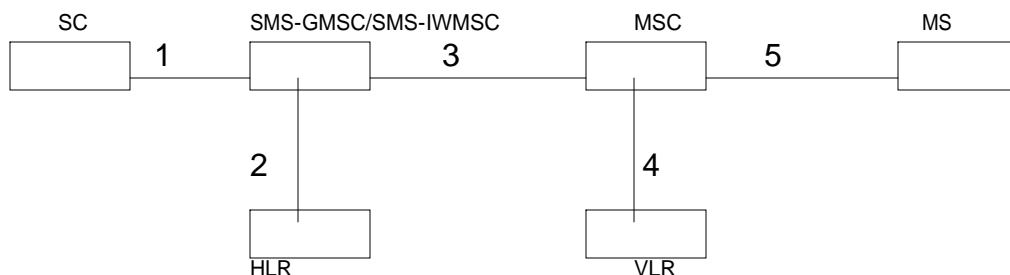
Let us see how GSM system provides SMS features. The GSM allocates carriers on 200 kHz channel centers, and transmits at a raw rate of 270.833 k bit/s. Transmissions are framed at a repeating period of 4.62 ms, and each frame comprises 8 slots of 576.9  $\mu$ s or 156.25 bit times. Slots can contain bursts of transmission in either direction. Several kinds of transmission burst are defined, of which only two carry user data. These are the normal burst and the access burst. A normal burst has a data payload of 116 bits; the rest of the 156.25 bit times being allocated for synchronization, guard time, training, and so on. The normal burst, as the name suggests, is the one intended to be used for almost all logical channels at the air interface. An access burst has a data payload of 36 bits; the bulk of the 156.25 bit times being idle guard time. An access burst is used only for random access to the air interface, and is designed to solve a particular problem of transmission physics, as it were. The issue is the unknown pure time delay from the mobile station to the base station receiving antenna at the time of random access. Because of the finite speed of radio transmission (about 300,000 km $\oplus$ s<sup>-1</sup>) for cells of radius over 30 km, there may be 100  $\mu$ s of more of difference between the arrival times of random access bursts launched by two MS s, one near a base station (BS) and another at the cell boundary. The design solution embodied in the access burst, used on the Random Access Channel (RACH), is to shorten the active transmission interval during the access burst so that heavily delayed transmissions from MS s near the cell boundary cannot “spill over” into adjacent time slots. In practice, the 116 bit payload of the normal burst and the 36 bit payload of the access burst are further reduced by coding for the logical channels that they carry. For example, in the specific case of a Broadcast Control Channel (BCCH) operating over normal bursts, 228 bits of data are run through a rate 1/2 convolution encoder, grossed up to 456 bits, and transmitted in an interleaved fashion in 4 normal bursts. These 228 bits are comprised of 184 bits (23 octets) of BCCH data, 40 bits of CRC, and 4 tail-bits for the convolution code. The coding model for the logical channels of the Paging Channel, Access Grant Channel, and Stand-Alone Dedicated Control Channel (PCH, AGCH, and (SDCCH) is similar. On the RACH, using access bursts, the 36 bits are used with a rate 1/2 convolution encoder to transport 18 bits of data, comprised of 8 bits (1 octet) of RACH data, 6 bits of CRC, and 4 tail-bits for the convolution code. Consider this information in the context of channel efficiency for a moment. First, let us calculate the time bandwidth product used for message transport. In the case of the SDCCH, we have a 200 kHz channel consumed for four time slots of 576.9  $\mu$ s, for a time-band width product (*BT*) of 461.5. This time-bandwidth unit carries 184 bits with a net efficiency of 184/461.5 = 0.399 bit/s/Hz. For the RACH, we have 8 bits in a single burst. The time-bandwidth unit is 115.3, and the efficiency is 0.07 bit/s/Hz. There is another effect that we need to account for here, however. The RACH is a slotted Aloha contention access channel, for which the theoretical maximum allocation efficiency is about 36% at infinite access delay. More practically, a single server slotted Aloha link will run at about 20% to 25% channel allocation efficiency in order to minimize access latency due to collisions and retries. This is in distinct contrast to the allocation of traffic channels for voice streams in a cell using the

typical Erlang B (blocked calls are dropped) call model. In modern digital cellular, with more than 60 available trunks/channels per cell, trunking efficiencies approach 100%. Adjusting the RACH to account for contention access efficiency will increase effective BT to around 500 and decrease the efficiency to about 0.016 bit/s/Hz. This 25-fold reduction in air interface efficiency constitutes a significant protocol design issue for GSM. The drafters of the GSM have drawn a distinction between purely random access to the air interface and managed access. Purely random access is, by design, a pathway to managed access; and the duration of time for which random access is supported during any transaction is, reasonably, limited.

In a cellular system like the GSM, the fundamental air interface resource of time-bandwidth product can be reused in an orderly manner as defined by the reuse number, N. The lower is N, the greater is the opportunity for BT reuse. In the original AMPS scheme, N =7. In the GSM, N = 3. For a service provider with access to a total bandwidth of, say 10 MHz, the time-bandwidth product available per busy-hour per cell would be  $3600 \text{ s} * 10 \text{ MHz} / 7 = 5.14 \times 10^9$  in the AMPS case, and  $1.2 \times 10^{10}$  in the GSM case.

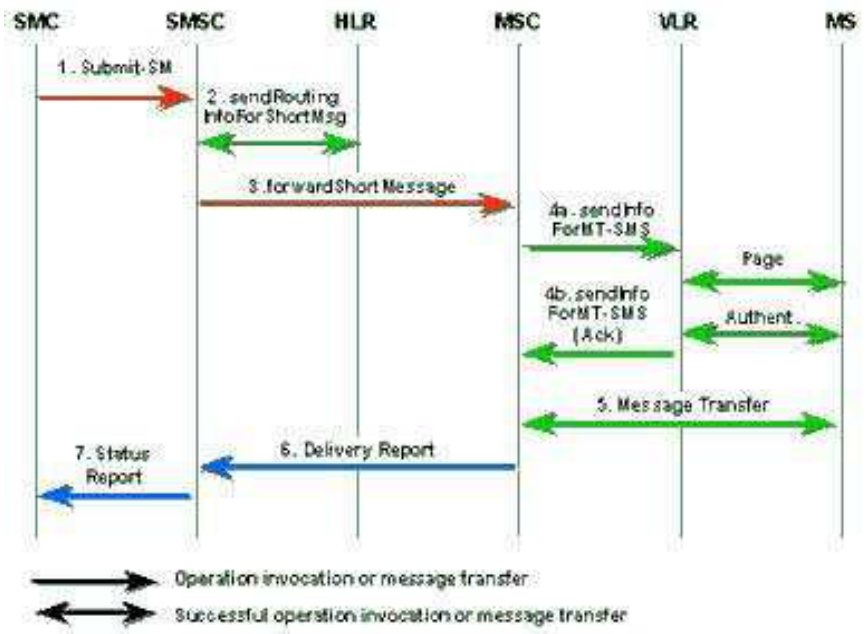
### SMS call patterns:

The reference model for short message service delivery is shown in Figure a.



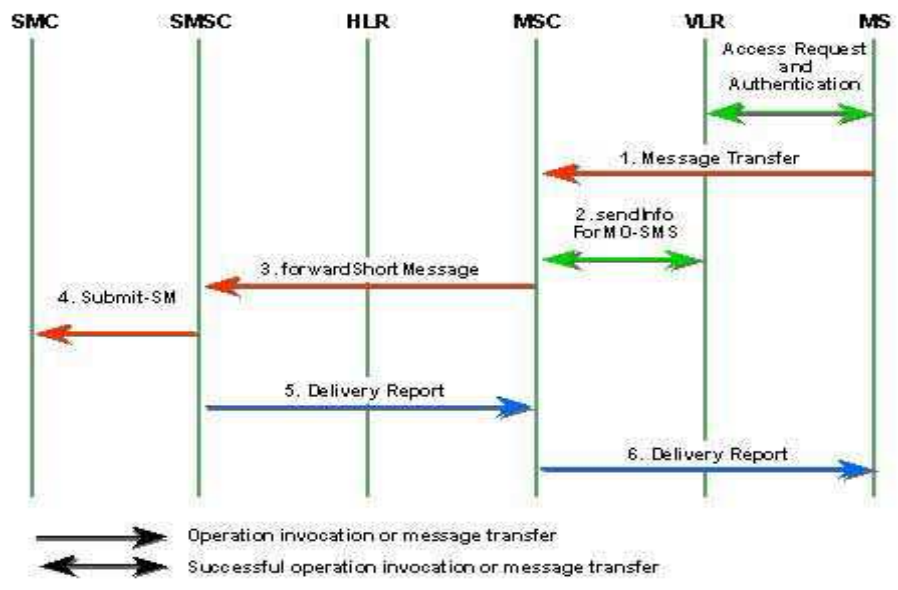
Reference Model for GSM SMS Fig a

In the forward direction, messages arrive at one or more Service Centers (SC) for Mobile Stations (MS). These messages are relayed to the MS through the Gateway, Home switch (MSC-HLR), and Visited switch (MSC-VLR). The SMS is delivered over a Stand-alone Dedicated Control Channel (SDCCCH). Idle devices do not operate on an SDCCH; and so, a call setup procedure for channel assignment to an SDCCH must be executed at the Visited switch upon the arrival of the SMS. As for any Mobile Terminated (MT) voice call setup, this will typically involve broadcast of a page to the MS on a PCH, MS response on a RACH, notification of channel assignment on an SDCCH via an AGCH, and then message delivery. With success, the message is finally acknowledged. This pattern is shown in the ladder diagram of Fig b.



Mobile Terminated Short Message Example Fig b

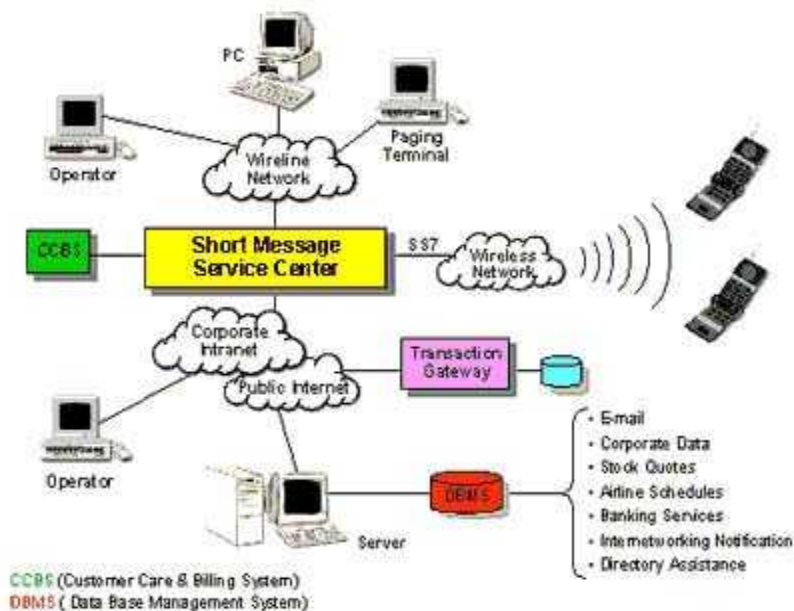
Mobile originated (MO) or inbound message transfer is similar, save that assignment to the SDCCH is done based on a MS request, initiated on the RACH, just as for voice call setup on a Mobile Terminated (MT) call which is shown in Fig c. The system replies on an AGCH with a re-direct to an SDCCH, and the message delivery proceeds.



Mobile-Originated Short Message Example

We can note that in order to complete an entire SMS delivery, air interface time-bandwidth resource is consumed at different rates at different stages of the process in order to accomplish the overall message delivery transaction. For example, the geographic scope of the outbound page to indicate a pending

message must include at least all cells within a Virtual Location Area (VLA).



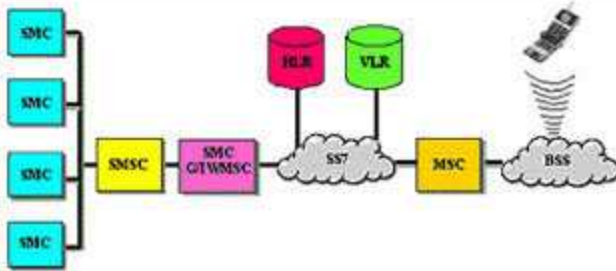
GSM Network Infrastructure Fig c

depending upon network configuration, failure of response in a VLA may lead to escalation of the page to a larger geography. Of course, such considerations are beyond the scope of the GSM standards as such; but this does not constrain their pragmatic value to the service provider attempting to optimize the balance between air time consumed and message delivery success.

Given that the SMS user is actually interested in the successful transmission or reception of the content of his or her message, then all of the other “payloads” previously described here are immaterial to them. An accurate measure of transaction efficiency would constitute an accounting of all air interface time bandwidth resource consumed in order to transport a successful message. This accounting should include any reuse efficiencies, or lack thereof. It should account for expected message retransmission probabilities due to errors or link failure. It should also include the effect of queuing, trunking, batching, and multiple access efficiencies. Using the ladder diagrams, one could proceed with a detailed analysis of air interface resource consumption on a transaction fragment by fragment basis. However, such an analysis is largely pointless in the face of a great simplifier; namely, once the MS is assigned to the SDCCH, it is consuming 1/64th of a full 200 kHz channel for the duration of time that the overall message transaction takes to complete. This time duration will typically not be dominated by the time to transfer message content, but instead will be controlled by delay times for messaging between network entities at different physical locations; for example, between MSC and BSC. Whether the SMS transaction is MO or MT, once the MS is active on the SDCCH, a bandwidth of  $200 \text{ kHz}/64 = 3.125 \text{ kHz}$  is fully dedicated to it. The pure transport delay time to move, say 100 octets of user data, at a rate of 23 octets per 4 bursts is about 20ms. However, this must be adjusted to account for the fact that any user has only 1/64th of the channel. The delay time becomes 1.28 s accounting for this fact. This pure transport delay

will easily be doubled by a round trip delay of several 100 ms for each MSC-BSC transaction.

Depending on how one counts, there are roughly four of these bi-directional MSC-BSC transactions:



Network Elements & Architecture Fig d

Call setup, authentication, cipher mode set, and call release. Let us go ahead and assume that these transactions will take about 2 s to complete, purely as an order of magnitude guess. In other words, this doesn't all happen in 100 ms or in 10 s. This simplifying assumption yields an estimate of  $BT = 2 \cdot 200 \times 10^3 \cdot 2 / 64 = 12,500$  for the part of the transaction executed on the SDCCH, whether or not it is MO or MT. [Note that we have doubled the bandwidth consumed since both the forward and reverse channels of the SDCCH are allocated even though message flow is dominantly unidirectional.] Let us assume that the average user payload being delivered is about 100 octets. As far as the distinction between MO and MT SMS is concerned, the key differences arise in use of RACH and AGCH for MO and PCH, RACH, and AGCH for MT. In the MO case, there is a net consumption of one RACH burst for call setup, ( $BT = 500$ ) and of one block on the PCH ( $BT = 460$ ). The net marginal  $BT$  for setup is 960 in the MO case. In the MT case, this is almost identical, save for a scaling factor on the PCH, which must be transmitted across a VLA. Let us assume, for the sake of argument, that a reference VLA comprises 15 cells. We then have an effective  $BT$  for MT setup of about 8,360. Assuming that traffic is roughly bi-directional, the expected  $BT$  consumption per message is  $(0.5 \cdot 960 + 0.5 \cdot 8,360) + 12,500 \approx 17,200$ . Since we have assumed that we move 100 octets, our aggregate efficiency in transport is about 0.047 bit/s/ Hz/cell, referenced to a successful message delivery.

Table 2 Reliability, costs and delay of SMS delivery methods

	Method 1	Method 2	Method 3	Method 4
Page success prob.	N/A	0.833	0.811	0.811
Delivery prob.	0.842	0.883	0.833	0.981
reliability	0.842	0.736	0.716	0.796
Normalized reliability	0.990	0.865	0.842	0.936

Four SMS delivery methods are analyzed in this paper: 1) The system directly broadcasts SMS messages to all cells in the system. 2) The system pages the zone where the mobile registered last time to determine the current cell of the mobile, then deliver SMS message to the cell. 3) The third approach is similar to 2), but the system pages the cell where the mobile registered last time, if the page fails, then the zone is paged. 4) The approach is similar to 3), but if the SMS delivery to the current cell fails (may be caused by mobile rescan), SMS delivery area is expanded to the adjacent area.

Measurements of different delivery methods in SMS Table 2

## **SMS DISADVANTAGES:**

However, it is also true to say that today's SMS has several disadvantages:

**LIMITED MESSAGE LENGTH** The unit short message length is currently limited to 140 octets because of limitations in the Mobile Application Part (MAP) signaling layer. It would be preferable to have a length that is several times this magnitude. Packet data services such as GPRS simplify non voice transactions over mobile networks because the amount of data that can be communicated in any one session is significantly higher than one or several short messages. This means that users are less likely to be constrained by the limitations of the underlying bearer. The transaction costs incurred by the user when retrieving any sizable information via SMS are likely to be higher than GPRS because of the need to handle multiple messages.

**INFLEXIBLE MESSAGE STRUCTURE** The structure of the SMS Protocol Data Unit as defined in the GSM 03.40 standard is inflexible. The Data Coding Scheme, Origination Address, Protocol Identifier and other header fields are fixed- this has constrained the number of possible scenarios that can be indicated when developing applications. For example, use of the Protocol Identifier has sometimes been constrained because one feature will nullify others: the flags are sometimes mutually exclusive, such that software developers cannot depict two characteristics simultaneously. The attempted solution for this so far has been to replicate the values, by, for example, stating the Message Class twice. However, this is inefficient. Instead, it is envisaged that the 3G specifications will include a Tag Length Variable structure. Each parameter in the header such as the Data Coding Scheme would be given a tag to indicate what kind of information is being sent in that field followed by a variable amount of information followed by another tag for the next field.

**RELATIVELY SLOW SIGNALING CHANNEL** The latency- turnaround time- of services such as General Packet Radio Service (GPRS) and Unstructured Supplementary Services Data (USSD) tends to be faster than that for SMS. The signaling channel is used for several other purchases besides SMS such as locating phones and managing call completion. Indeed, as SMS traffic volumes have grown, network operators have expressed some concern about potential service outages due to over use of and corresponding degradation in scarce signaling resources.

**ALWAYS STORE AND FORWARD** Today's SMS is designed such that every short message always passes through the SMS Center. Variations on this have been discussed at UMTS committee level such as forward messages and optionally store them: immediately attempt delivery and if the message cannot be delivered, then store it. This reduces the processing power needed by the SMS Center. It is clear that in cases such as requests from the phone for information (either directly using SMS Mobile Originate or indirectly using the Wireless Application Protocol (WAP)); the requesting terminal is highly likely to be available to receive the response. As such, the possibility has been discussed of a mobile to mobile Short Message Service without an SMS Center.

**Comments and Conclusions:** Use of the GSM-SMS system will provide enormous benefits

**Cost Savings** By opting for a wireless system, significant amounts of resources. The continued lowering cost of GSM-SMS transmission will also make the system more cost effective in the future.

**Ease of Expansion** No additional equipment needs to be installed when expanding to a new area or region.

**Ease of Upgrade.** The GSM SMS is designed with the future in mind. It could easily be upgraded to take advantage of new technologies, especially with the expected entry of 3G cellular technology in the next few years.

**Future Opportunities** We see the GSM SMS as a continuously improving and innovating design that will keep up with the break neck pace of innovation in digital telecommunications. We see no limit to the potential of the GSM SMS for industrial applications, specifically in the realms of telemetry and remote command and control, and with improvements in telecommunications technology occurring every year, so will the SMS Systems improve and innovate.

*References:*

- 1) *SMS Messaging in SS7 Networks: Optimizing Revenue with Modular Components Intel Publications.*
- 2) *Reliability, Costs and Delay Performance of s ending Short Message Service in Wireless Systems. Hua Jiang Nortel Richardson TX.*
- 3) *A System for Basic -Level Network Fault Management Based on GSM Short Message Service (SMS) Stavros Vougioukas and Manos Roumeliotis.*
- 4) *NEXT MESSAGING: An Introduction to SMS, EMS and MMS <http://www.mobilestreams.com>*
- 5) *An Evaluation of Mobile Phone Text Input Methods: Lee Butts and Andy Cockburn Human Computer Interaction Lab. University of Canterbury New Zealand.*
- 6) *The Future of SMS: Empower Interactive Group*
- 7) *Wireless Data Transm ission over GSM Short Message Service (GSM - SMS). EACOMM Corporation.*
- 8) *Short Message Transfer in Narrowband and Broadband PCS: Web Link Wireless.*
- 9) *Global Mobile Data Guide: ETSI Specification for GSM technology*
- 10) *Analysis of WAP over SMS -GSM Andreadis A., Benel li G., Giambene G., Marzucchi B. Department of Information Engineering University of Siena, Italy.*
- 11) *Short Message Service Center Tutorial : Telecommunication Systems.*