Capacity Analysis of the GSM Short Message Service

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Motivation

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"SMS volumes soar on New Year's eve", January 3, 2004, Business Standard.

Short messaging shot through the roof this New Year's eve with an unprecedented 180 per cent increase in volumes to 60 million SMS compared with last year's 21 million...
...SMS and data contributed to 40 per cent of the cellular operators' revenues. With increase in SMS volumes, analysts point out that the share is expected to increase this quarter...

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- Interesting measures of the SMS service -

  1. Blocking probability (“Network Busy”)
  2. End-to-end delay

More Questions for Analysis

- What are the bottleneck resources?
- How should they be modeled?
- How can their usage be characterized and parameterized?

Overview of SMS

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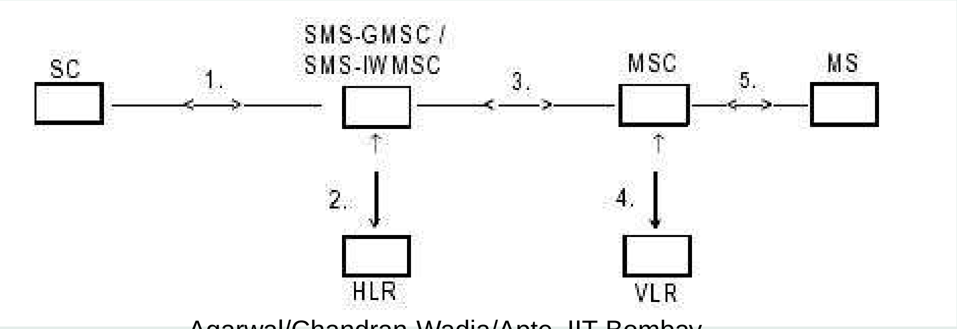
- Sending a Mobile Terminated SMS:



Resources Required by SMS

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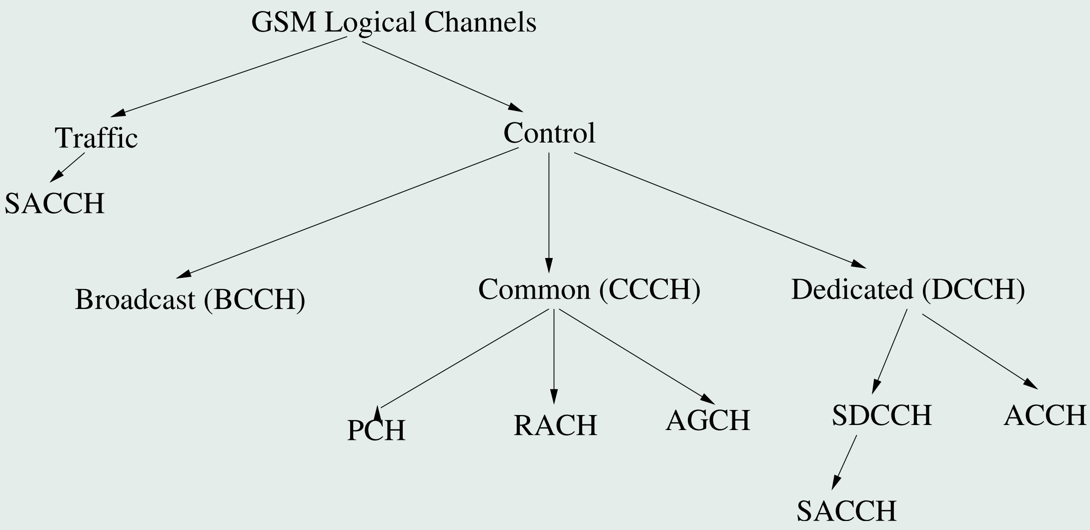
We focus on the GSM channels as bottleneck resources, and blocking as the primary measure of interest.

Analysis Approach

1. Identify traffic sources with which SMS shares resources (Channels)
2. Characterize volumes of all relevant traffic
3. Characterize channel holding time requirement by different types of traffic
4. Model the shared resource appropriately
5. Derive required perormance measures

GSM Channels

- Logical channels mapped to physical channels
- Logical channels:



GSM Channel Usage

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- Channel usage by voice calls:

Steps	Channel	MS	BTS	BSC	MSC
1. Channel Request	RACH		→	→	
2. Channel Assigned	AGCH	←	←		
3. Call Establishment Request	SDCCH		→	→	→
4. Authentication Request	SDCCH	←	←	←	
5. Authentication Response	SDCCH		→	→	→
6. Ciphering Command	SDCCH	←	←	←	
7. Ciphering Ready	SDCCH		→	→	→
8. Send Destination Address	SDCCH		→	→	→
9. Routing Response	SDCCH	←	←	←	
10. Assign Traffic Channel	SDCCH		→	→	
11. Traffic Channel Establishment	FACCH	←	←		
12. Available/Busy Signal	FACCH	←			
13. Call Accepted	FACCH	←	←	←	
14 Connection Established	FACCH		→	→	→
15. Information Exchange	TCH	←			→

...GSM Channel Usage

- Location Update: Similar to voice call set up (no TCH assigned, update continues on SDCCH)
- SMS: Similar to voice call (no TCH assigned, data transfer continues on SDCCH).

  If overlapping with voice call, sequence & channels slightly different

Physical Channel Allocation

- Physical channel defined by: (Frequency, Timeslot). Some control, some traffic.
- 1 control multiframe made of 51 frames, lasts for 235.5 ms
- SDCCH occupy 32 slots in the multiframe, in eight groups of 4 slots each.
- Each group of four serves one user, thus each such channel can serve 8 users

This information used to derive time taken to transfer data

Queueing Model for SMS

- Erlang loss model ($M/G/s$)
  - Servers are SDCCH channels
  - Customers are of three types: SMS, voice call setup, location update
  - Assume Poisson arrivals
- Channel holding time: Weighted average of holding time of the three types of messages
- Apply Erlang-B formula for blocking probability

Modeling SMS fragmentation

- Maximum allowed size of an SMS is 160 charachters (140 octets)
- Larger message split into fragments, and sent as separate SMS
- Model this by simply multiplying the arrival rate by the average number of fragments

Modeling re-attempts

- We assume a re-attempt probability r after blocking
- If λ is the total arrival rate, and B is the blocking probability, effective arrival rate will be:

$$\lambda_{eff} = \lambda/(1 - rB).$$

Now, model must be solved using iteration.

Model Parameterization

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- Number of cells in Mumbai: 50
- SMS arrival rate: 1 Million messages per day (assume sent in 10 peak hours) = 0.55 SMSes/second
- Number of voice calls: 12 times as much as SMSes
- Voice call set up time on SDCCH channels: Based on GSM connect time requirement of 4 seconds

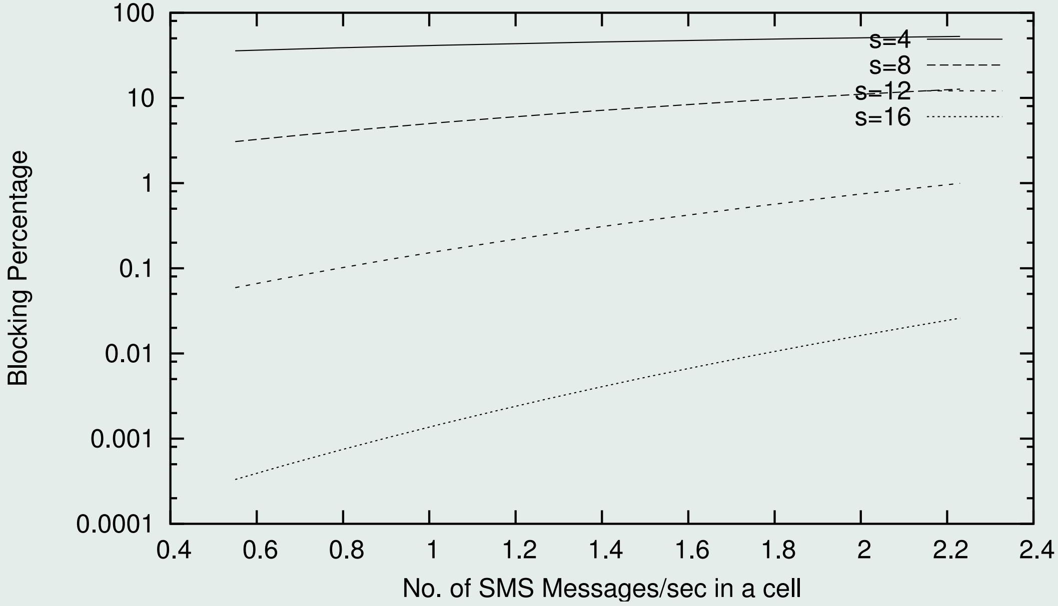
SMS transfer time on SDCCH

- 1 control multiframe has 4 SDCCH slots given to one user
- Control multiframe lasts for 235.5 ms
- Data carried per slot: 114 bits, so total=456 bits
- For signalling channel: 184 bits of data is encoded as 456 bits
- Thus 4 SDCCH channel carry 184 bits per 235.5ms
- SMS message of size c characters : $7c$ bits
- Time to carry c character SMS = $(7c/184) \times 235.5 = 9c$ ms.

Results

Average Message Size = 70 characters

Note: Blocking Probability is for ALL traffic (including voice call set-up)



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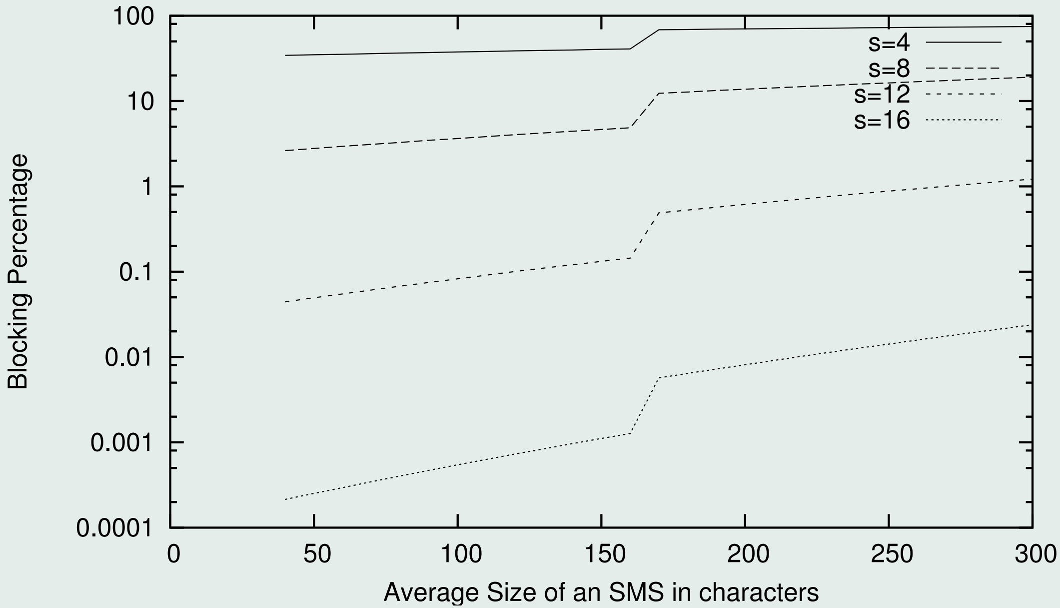

Summary

- Main finding: SMS contends with voice call set-up, a critical function.
- If SDCCH channels become bottleneck, it will impact voice call set-up also.
- As many applications are beginning to ride over SMS, this will be an important design issue.

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Thank You!