The GSM Traffic Channel Capacity With(out) High Speed Circuit Switched Data

- The results are represented for High Speed Circuit-Switched Data (HSCSD) traffic channels co-existing with the voice traffic channels in a GSM cell.
- In a GSM system the base station has a finite number of traffic channels, from which one voice terminal occupies one traffic channel.
- The admission priority for voice services is higher than that of the HSCSD data.
- On the other hand, one HSCSD terminal can occupy multiple number of channels if needed, provided that they are available. The HSCSD terminal will release its reserved traffic channels only after the data transmission is completed.
- The presence of HSCSD services slightly increases the blocking probability of the voice terminals.

The GSM Traffic Channel Capacity With(out) High Speed Circuit Switched Data (cont'd)

- The results show the steady-state channel utilization and blocking probability of voice terminals under the constraints where voice terminals occupy one traffic channel at a time and data terminals can occupy multiple number of traffic channels.
- The results show that for a defined acceptable voice blocking probability, the overall channel utilization increases with the higher number of HSCSD terminals allowed per base station as well as with the higher number of channels allowed to be allocated for each HSCSD terminal.
- The traffic channel utilization also increases if the acceptable blocking probability for voice terminals is allowed to increase.

Scope and contents

- Analytical performance evaluation of the GSM traffic channel capacity with High Speed Circuit Switched Data (HSCSD)
- Results
  - channel utilization
  - blocking probability for voice terminals
  - optimum number of traffic channels per base station

System Features

- ETSI standards in Phase 2+
  - GSM with
    - HSCSD
    - GPRS
- The traditional GSM
  - finite number of traffic channels per base station
  - one voice terminal occupies one traffic channel
  - one data terminal occupies one traffic channel
  - voice has higher priority to data

System Features (cont'd)

- HSCSD
  - one HSCSD terminal can occupy multiple traffic channels, if requested and if they are available for admission
  - the traffic channels are released only after the data transmission is complete ie the channel occupancy extends till the session is over
  - blocking probability for voice terminals increases
  - what happens to the traffic channel utilization in the system with HSCSD ?

System Features (cont'd)

- GPRS
  - performs better in terms of dynamic traffic channel utilization
  - voice blocking probability is less than for HSCSD

Bitrate evolution for data

- The GSM
  - data rates 14.4 kbps and 28.8 kbps
- HSCSD
  - data rates up to 64 kbps or even up to 76 kbps
- GPRS
  - data rates up to 115 kbps, or even more
- The 3rd generation technologies
  - data rates up to 144 kbps in vehicular
  - data rates up to 384 kbps in outdoor and indoor
  - data rates up to 2 Mbps in indoor environment

Analysis

- The steady-state channel utilization, and blocking probability of voice terminals is analysed.
  - voice terminals occupy one channel at a time
  - data terminals can occupy multiple number of channels
- Analytical model is studied to show that
  - for an acceptable voice blocking probability, the channel utilization, in the system, increases with the higher number of HSCSD terminals and with the higher number of traffic channels allocated for each HSCSD terminal.
  - The traffic channel utilization increases, if the acceptable blocking probability for voice terminals is allowed to increase.

Mathematical Notation

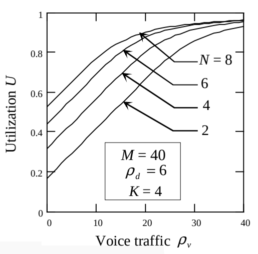
- Base station having *M* number of traffic channels.
- The call arrival of voice terminals is independent with average rate of λ_v.
- The duration of each voice call is exponentially distributed with mean $1/\mu_v$.
- voice traffic intensity of *all* voice terminals

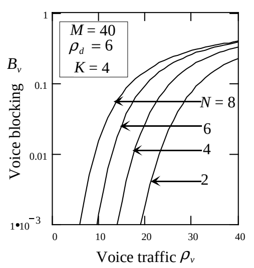
$$\rho_v = \lambda_v / \mu_v$$

Mathematical notation (cont'd)

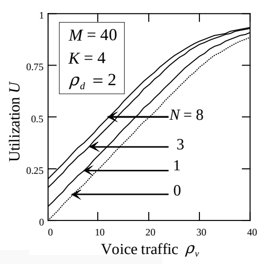
- The maximum number of admitted data terminals in a base station is *K*.
- Each data terminal can occupy maximum *N* slots ie *N* channels.
- Two assumptions were made:
  - Multiple channel arrival process is independent and exponentially distributed with mean λ_d
  - Multiple departure process is independent and exponentially distributed with mean μ_d
- The call intensity of *each* data terminal $\rho_d = \lambda_d / \mu_d$.

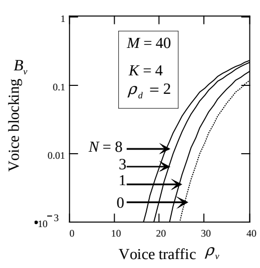
Channel Utilization and Blocking Probability for Voice Terminal



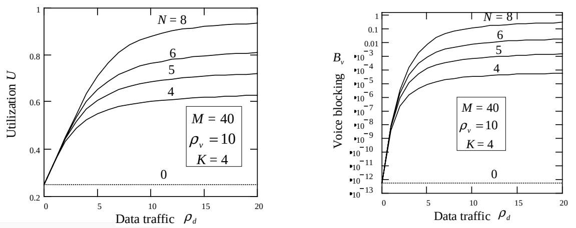


Channel Utilization and Blocking Probability for Voice Terminal

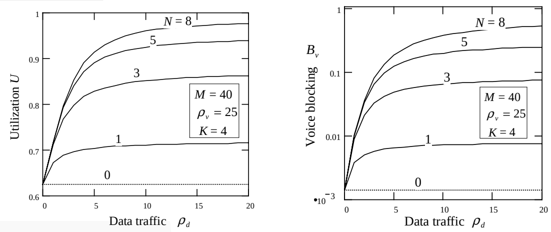




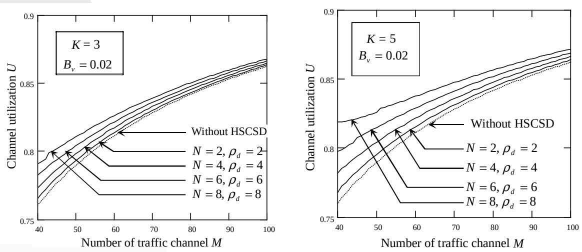
Channel Utilization and Blocking Probability for Voice Terminal



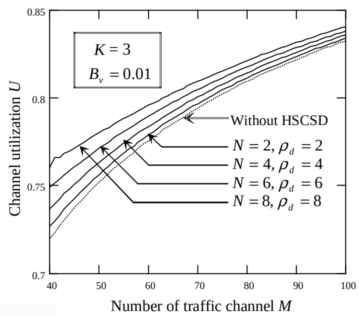
Channel Utilization and Blocking Probability for Voice Terminal



Optimum Number of Traffic Channels Per Base Station



Optimum Number of Traffic Channels Per Base Station



HSCSD - for improved traffic channel utilization ?

$K = 5$ $B_v = 0.02$

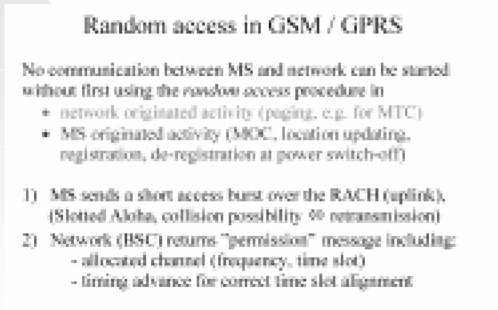
	No HSCSD		$\rho_d = 2, N = 2$		$\rho_d = 4, N = 4$		$\rho_d = 6, N = 6$		$\rho_d = 8, N = 8$	
M	ρ_v	U	ρ_v	U	ρ_v	U	ρ_v	U	ρ_v	U
40	31.012	0.76	25.276	0.768	17.974	0.782	10.203	0.798	2.372	0.819
50	40.322	0.79	34.542	0.796	27.093	0.805	19.243	0.815	11.117	0.826
60	49.703	0.812	43.884	0.816	36.37	0.822	28.431	0.829	20.291	0.838
70	59.182	0.828	53.334	0.831	45.774	0.836	37.775	0.842	29.558	0.848
80	68.736	0.842	62.865	0.844	55.27	0.848	47.228	0.852	38.957	0.857
90	78.35	0.853	72.461	0.855	64.839	0.858	56.763	0.861	48.451	0.865
100	88.012	0.862	82.109	0.864	74.465	0.866	66.362	0.869	58.019	0.872

Conclusions

- Analytical performance evaluation was carried out to show the channel utilization with(out) the HSCSD.
- The results show that for a defined acceptable voice blocking probability, the overall channel utilization increases with the higher number of HSCSD terminals allowed per base station
  - as well as with the higher number of channels allowed to be allocated for each HSCSD terminal.
- Operators may deploy HSCSD and GPRS technologies to enhance the GSM capabilities

Questions

Estimation of the Random Access Slots for GSM Evolution and its Impacts on Traffic Channel



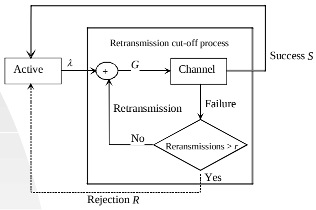
Random access in GSM / GPRS

No communication between MS and network can be started without first using the *random access* procedure in

- network originated activity (paging, e.g. for MTC)
- MS originated activity (MOC, location updating, registration, de-registration at power switch-off)

1) MS sends a short access burst over the RACH (uplink). (Slotted Aloha, collision possibility ⇔ retransmission)
2) Network (BSC) returns "permission" message including:
   - allocated channel (frequency, time slot)
   - timing advance for correct time slot alignment

Slotted ALOHA with re-transmission cut-off



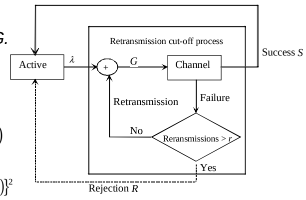
- According to specifications, a maximum of *r* retransmissions are allowed for each mobile call during the access period. The parameter *r* can be set to four different possible values 1, 2, 4 or 7

Slotted ALOHA with re-transmission cut-off

- 1st time transmission is λ .
- Including *r* times retransmissions *G*.
- The probability of success

$$P(Su) = \frac{G^0}{0!}\exp(-G) = \exp(-G)$$

- The probability of failure $1-\exp(-G)$
- 1st retransmission $\lambda\{1-\exp(-G)\}$
- 2 times failure probability $\{1-\exp(-G)\}^2$
- 2nd retransmission $\lambda\{1-\exp(-G)\}^2$
- -
- *r*th retransmission traffic $\lambda\{1-\exp(-G)\}^r$
- Aggregated traffic $G = \sum_{i=0}^{r}\lambda\{1-\exp(-G)\}^i = \frac{\lambda\left[1-\{1-\exp(-G)\}^{r+1}\right]}{\exp(-G)}$



Performance Analysis (Throughput)

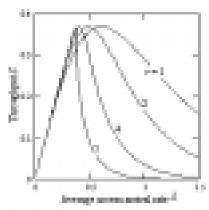
$$S = [\text{Offered load}]\text{Probability of success}$$

$$= \begin{bmatrix}\text{new packet generation rate} + \text{1st retransmission} + \\ \text{2nd transmission} + \ldots + r\text{th retransmission}\end{bmatrix}\text{Probability of success}$$

$$= \left[\lambda + \lambda\{1-\exp(-G)\} + \ldots + \lambda\{1-\exp(-G)\}^r\right]\exp(-G)$$

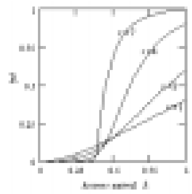
$$S = \lambda\left[1-\{1-\exp(-G)\}^{r+1}\right]$$

- But we prefer *r* =7, see next



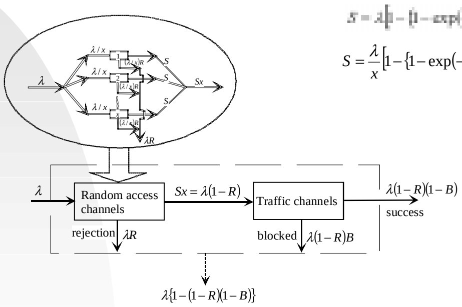
Performance Analysis (Call rejection probability)

- Probability of failure after 1st transmission $\{1-\exp(-G)\}$
- Probability of failure after 1st retransmission $\{1-\exp(-G)\}^{1+1}$
- -
- Probability of failure after *r*th retransmission $\{1-\exp(-G)\}^{r+1}$
- The call rejection probability $R = \{1-\exp(-G)\}^{r+1}$



Overall GSM System Model

$$S = \frac{\lambda}{x}\left[1 - \{1 - \exp(-G)\}^{r+1}\right]$$



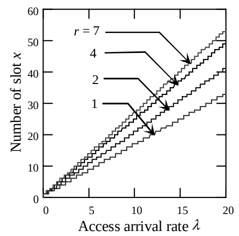
State the purpose of the discussion

- How many slots will be mapped in a given time?
- A fixed number of random access channels (slots) are mapped into a normal GSM system, five different configurations of the RACH with approximately 400,000 and n*780,000 RACH slots per hour (n=1, 2, 3, 4).
- The procedure for optimisations of random access slots is described.

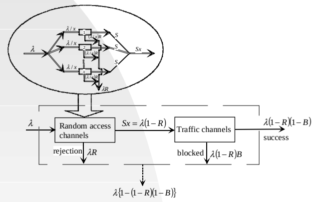
The Optimum number of random access slots

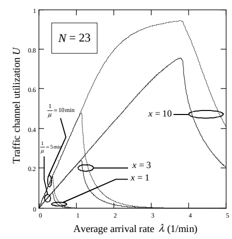
$$S = \frac{\lambda}{x}\left[1 - \{1 - \exp(-G)\}^{r+1}\right] \qquad \lambda / x = \frac{G\exp(-G)}{1 - \{1 - \exp(-G)\}^{r+1}}$$

$$G = 1 \qquad S = e^{-1} \qquad x = \left\lfloor \lambda e\left\{1 - \left(1 - e^{-1}\right)^{r+1}\right\}\right\rfloor$$



What This Means: Traffic Channel utilization

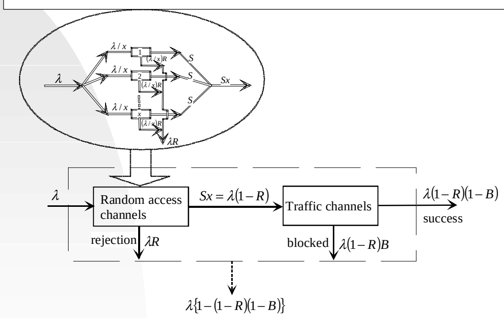




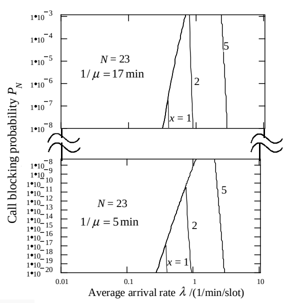
$$= \frac{(Sx/\mu)}{N} a[1 - p(N)]$$

$$p(N) = \frac{(S_v x/\mu_v)^N / N!}{\sum_{i=0}^{N} (Sx/\mu)^i / i!}$$

Call Rejection and Blocking Probabilities



Call Blocking Probability



Conclusions

- The estimation of the random access slots in a GSM based network is analyzed.
- The access throughput depends on the number of random access slots per time unit.
- The exact number of random access slot needed for a given average arrival rate is derived analytically.
- The traffic channel utilisation for different number of random access slot is derived.
- The traffic channel utilisation will be sufficiently low, if less number of random access slots are implemented. The reason for that is more access will be rejected in the access part.
- The analytical results of the call rejection probability and the call blocking probability are obtained.

Questions