# DECT

- What is DECT?
- Radio Interface of DECT

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## What is DECT?

- DECT (Digital Enhanced Cordless Telecommunications) is a flexible digital radio access standard for cordless communications in residential, corporate and public environments.
- DECT provides for voice and multimedia traffic, and contains many forward-looking technical features that allow DECT-based cordless systems to play a central role in important new communications developments such as Internet access and interworking with other fixed and wireless services such as ISDN and GSM.
- The DECT standard makes use of several advanced digital radio techniques to achieve efficient use of the radio spectrum; it delivers high speech quality and security with low risk of radio interference and low power technology.
- TDMA (Time Division Multiple Access) radio access, with its low radio interference characteristics, provides high system capacity to handle up to 100’000 users per km² floor space in an office environment.

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## What is DECT?

- ADPCM (Adaptive Differential Pulse Code Modulation) speech encoding ensures a DECT cordless phone very high speech quality, comparable to wireline telephony.
- DCS/DCA (Dynamic Channel Selection / Allocation) is a unique DECT capability that guarantees the best radio channels available to be used. This happens when a cordless phone is in stand-by mode, and throughout a call. This capability ensures that DECT can coexist with other DECT applications and with other systems in the same frequency, with high-quality, robust and secure communications for end-users.
- Other features of the DECT standard include encryption for maximum call security and optimized radio transmission for maximum battery life.
- DECT basic technology and the various profiles enhance the DECT standard, introducing evolutionary applications and services. The GAP profile, for example, ensures interoperability of equipment from different providers for voice applications

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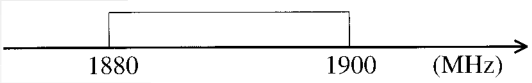
## Radio Interface of DECT

- DECT is a TDD system, which means that down- and uplink use the same frequency (but different time slots).

Frequency band of DECT



Two advantages of TDD over FDD

- can adapt asymetric traffic
- reciprocal radio channel

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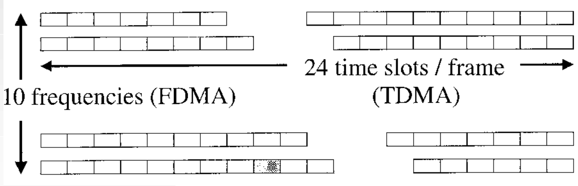
## Radio Interface of DECT

- Like GSM, DECT is a FDMA/TDMA system. The multiple access structure uses 10x12=120 bi-directional channels.
- Each channel can carry 32 kbits/s



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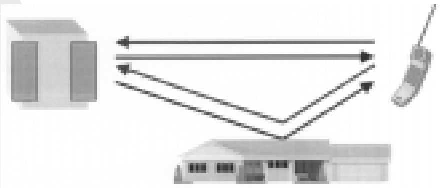
## TDD: reciprocal radio channel

- FDD system(e.g., GSM): Signal fading due to multipath propagation is different in uplink and downlink

closed loop power control needed



TDD system(e.g., DECT): Multipath fading is exactly the same in uplink and downlink.

- Open loop power control

## Multipath mechanism of fading

Suppose the signal arrives via two propagation paths at the receiver, and the received signal replicas have the same strength ($a$) but arrive after different delays ( $\tau_1$ and $\tau_2$ )

At frequency $f_1$ $$r_1(t) = a\left(e^{j2\pi f_1\tau_1} + e^{j2\pi f_1\tau_2}\right)e^{j2\pi f_1 t}$$

At frequency $f_2$ $$r_2(t) = a\left(e^{j2\pi f_2\tau_1} + e^{j2\pi f_2\tau_2}\right)e^{j2\pi f_2 t}$$

Where $r_1(t)$is fading, $r_2(t)$ may be strong (or vice versa), if the frequency and/or delay difference is sufficiently large.

## Dynamic channel selection and allocation

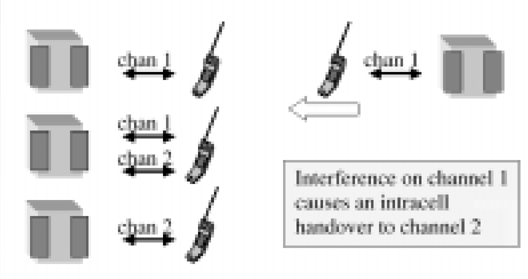
- All ideal channels are scanned at regular intervals (30 s).
- An RSSI (Received Signal Strength Indication) list is generated.
- When a new channel is needed, the DECT terminal (PP= or base station (FP) selects an ideal channel with minimum interference for this purpose, utilizing the RSSI list.
- In this way, the interference level in the DECT network is kept as low as possible.

## Mobile-controlled handover

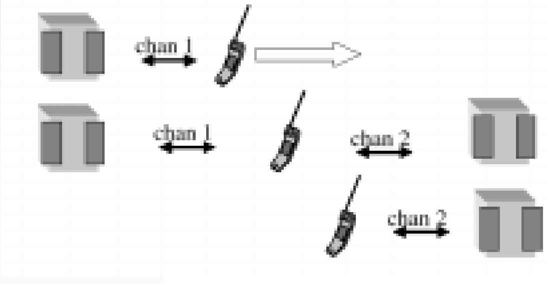
MCHO: handover is always initiated by the terminal /PP (PP=DECT portable port)

- (1) uplink interface⇒intracell handover to a better channel (at another frequency)
- (2) downlink interface ⇒Base station (RFP) signals to terminal ⇒ intracell handover
- (3) intercell handover due to better quality connection to another base station

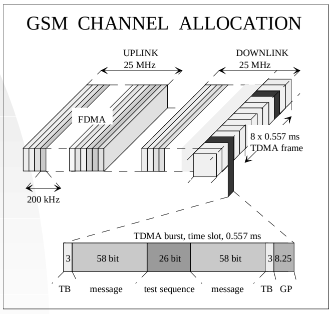
## Intracell Handover



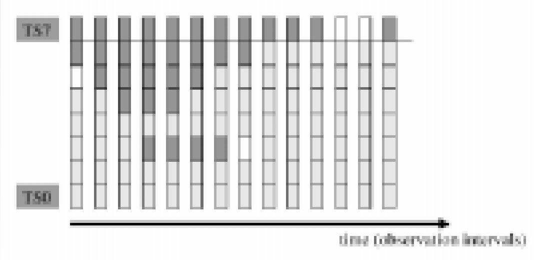
## Intercell Handover



## Erlang Loss Formula for GSM Radio Interface



## GSM channel allocation example



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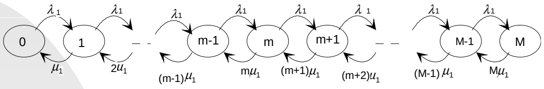
## State Diagram and state probabilities



$$p_0\lambda_1 = p_1\mu_1$$

$$\Rightarrow p_1 = p_0\frac{\lambda_1}{\mu_1}$$

$$p_1\lambda_1 = p_2(2\mu_1)$$

$$\Rightarrow p_2 = p_1\frac{\lambda_1}{2\mu_1}$$

$$\Rightarrow p_2 = p_0\frac{\lambda_1}{\mu_1}\frac{\lambda_1}{2\mu_1}$$

$$\Rightarrow p_2 = p_0\frac{1}{2}\left(\frac{\lambda_1}{\mu_1}\right)^2$$

$$p_2\lambda_1 = p_3(3\mu_1)$$

$$\Rightarrow p_3 = p_2\frac{\lambda_1}{3\mu_1}$$

$$\Rightarrow p_3 = p_0\frac{1}{2}\left(\frac{\lambda_1}{\mu_1}\right)^2\frac{\lambda_1}{3\mu_1}$$

$$\Rightarrow p_3 = p_0\frac{1}{3!}\left(\frac{\lambda_1}{\mu_1}\right)^3$$

$$\Rightarrow p_m = p_0\frac{1}{m!}\left(\frac{\lambda_1}{\mu_1}\right)^m$$

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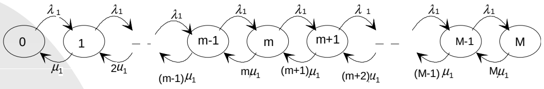
## State Diagram and state probabilities



$$\Rightarrow p_m = p_0\frac{1}{m!}\left(\frac{\lambda_1}{\mu_1}\right)^m \qquad \sum_{m=0}^{M} p_m = 1$$

$$\Rightarrow p_0 + p_1 + p_2 + p_3 + \ldots + p_{m-1} + p_m + p_{m+1} + \ldots + p_{M-1} + p_M = 1$$

$$\Rightarrow p_0 + \frac{\lambda_1}{\mu_1}p_0 + \frac{1}{2!}\left(\frac{\lambda_1}{\mu_1}\right)^2 p_0 + \frac{1}{3!}\left(\frac{\lambda_1}{\mu_1}\right)^3 p_0 + \ldots\frac{1}{(m-1)!}\left(\frac{\lambda_1}{\mu_1}\right)^{m-1} p_0 + \frac{1}{m!}\left(\frac{\lambda_1}{\mu_1}\right)^m p_0 + \frac{1}{(m+1)!}\left(\frac{\lambda_1}{\mu_1}\right)^{m+1} p_0$$

$$+ \ldots + \frac{1}{(M-1)!}\left(\frac{\lambda_1}{\mu_1}\right)^{M-1} p_0 + \frac{1}{M!}\left(\frac{\lambda_1}{\mu_1}\right)^M p_0 = 1$$

$$\Rightarrow p_0\sum_{k=0}^{M}\frac{1}{k!}\left(\frac{\lambda_1}{\mu_1}\right)^k = 1$$

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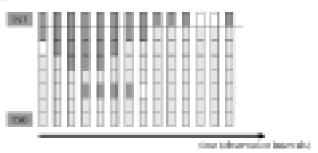
## Erlang Loss Formula for GSM Radio Interface

$$\Rightarrow p_m = p_0\frac{1}{m!}\left(\frac{\lambda_1}{\mu_1}\right)^m \qquad \Rightarrow p_0 = \left[\sum_{k=0}^{M}\frac{1}{k!}\left(\frac{\lambda_1}{\mu_1}\right)^k\right]^{-1}$$

$$p_m = \frac{\frac{1}{m!}\left(\frac{\lambda_1}{\mu_1}\right)^m}{\sum_{i=0}^{M}\frac{1}{i!}\left(\frac{\lambda_1}{\mu_1}\right)^i} \qquad 0 \le m \le M$$



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## Channel Capacity for Discontinuous Traffic Sources in a Cellular System

- Modelling of the discontinuous traffic sources
- GSM/GPRS channel structure
- Traffic channel capacity
- Frame based analysis considering voice activity
- Performance result with voice activity factor
- Conclusions

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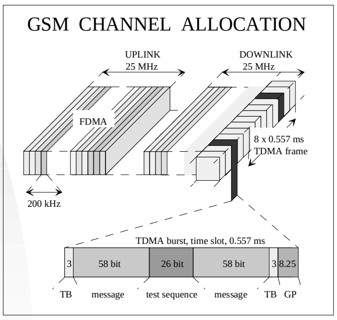
## Purpose of the discontinuous model

- The core network of the UMTS system at least partly will be Global System for Mobile (GSM) based.
- The initial implementation of GSM was for the voice communications.
- IP based data transmission is increasing
- GPRS can support it.
- A proper analytical tool is needed for discontinuous voice transmission is needed.

# GSM channel structure



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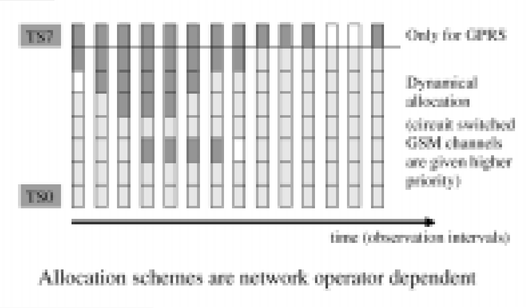
# GSM-GPRS channel allocation example



Allocation schemes are network operator dependent

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# Traffic channel capacity

Erlang Loss formula is widely used for the analysis of normal telephone networks.

$$r_m = \frac{(\lambda_1/\mu_1)^m / m!}{\sum_{k=0}^{M} (\lambda_1/\mu_1)^k / k!}$$

$$S1 = \frac{1}{M}\sum_{m=0}^{M} m r_m = \frac{1}{M}\left(\frac{\lambda_1}{\mu_1}\right)(1 - r_M)$$

$$r_M = \frac{(\lambda_1/\mu_1)^M / M!}{\sum_{k=0}^{M} (\lambda_1/\mu_1)^k / k!}$$

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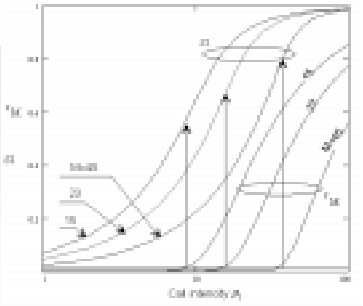
# Numerical Analysis



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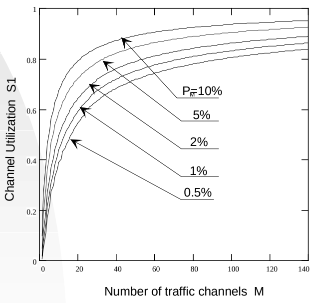
# Utilisation with same blocking probability



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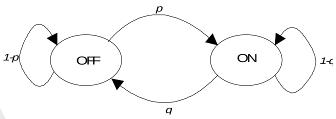
# Voice activity factor



- The probability of going from ON state to OFF state after *j* time slots (one successful slot for going ON state to OFF state followed by *j*-1 unsuccess slots) is: $P(j) = (1-q)^{j-1} q \quad j \geq 1$
- Therefore, the expected number of traffic (bursts) is: $E_B[j] = \sum_{j=1}^{\infty} jP(j) = 1/q$
- The transition from ON to OFF or from OFF to ON is independent in nature. The probability of going from OFF state to ON state again after *k* time slots is: $P(k) = (1-p)^{k-1} p \quad k \geq 1$
- The expected number of slots spent in the OFF state (no traffic generation) is: $E_S[k] = \sum_{k=1}^{\infty} kP(k) = 1/p$

## Frame based analysis considering voice activity

$$a = \Pr[\text{a dedicated voice channel's slot is in transmission mode}]$$
$$= \frac{1/q}{1/q + 1/p} = \frac{p}{p+q}$$

- Now it has been shown that *all users use m channels out of M channels*. So we have *m* discontinuous users in a base station. Within these *m* discontinuous users all are not in the transmission mode at the same frame. The probability that *i* out of *m* in transmission mode is

$$r_i(m) = \binom{m}{i} a^i (1-a)^{m-i} \qquad 0 \le i \le m$$

## Performance result with voice activity factor

$$r_i = \sum_{m=0}^{M} r_i(m) r_m = \sum_{m=i}^{M} r_i(m) r_m \qquad r_i(m) = 0 \text{ for } \quad m < i$$

$$S2 = \frac{\sum_{i=0}^{M} i r_i}{M} \quad = \frac{1}{M} \sum_{i=1}^{M} i \sum_{m=i}^{M} r_i(m) r_m$$

$$= \frac{1}{M} \sum_{i=1}^{M} i \sum_{m=i}^{M} \frac{(\lambda_1/\mu_1)^m / m!}{\sum_{m=0}^{M} (\lambda_1/\mu_1)^m / m!} \binom{m}{i} a^i (1-a)^{m-i}$$

$$= \frac{(\lambda_1/\mu_1) a}{M} \sum_{i=1}^{M} \sum_{m=i}^{M} \frac{\frac{(\lambda_1/\mu_1)^{m-1}}{(m-1)!}}{\sum_{m=0}^{M} (\lambda_1/\mu_1)^m / m!} \frac{\frac{(m-1)!}{(m-i)!(i-1)!}}{1} a^{i-1} (1-a)^{m-i}$$

## Performance result with voice activity factor

$$m' = m - 1$$

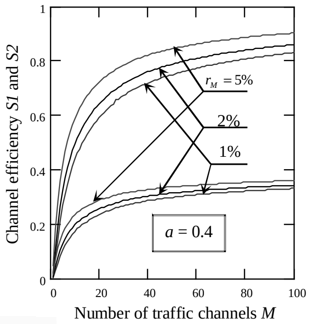
$$\Rightarrow \frac{(\lambda_1/\mu_1) a}{M} \sum_{i=0}^{M-1} \sum_{m'=i}^{M-1} \frac{\frac{(\lambda_1/\mu_1)^{m'}}{m'!}}{\sum_{m=0}^{M} (\lambda_1/\mu_1)^m / m!} \frac{\frac{m'!}{(m'-i)!i!}}{1} a^i (1-a)^{m'-i}$$

$$= \frac{(\lambda_1/\mu_1) a}{M} \left[ \sum_{i=0}^{M} \sum_{m'=i}^{M} \frac{\frac{(\lambda_1/\mu_1)^{m'}}{m'!}}{\sum_{m=0}^{M} (\lambda_1/\mu_1)^m / m!} \frac{\frac{m'!}{(m'-i)!i!}}{1} a^i (1-a)^{m'-i} - \frac{\frac{(\lambda_1/\mu_1)^M}{M!}}{\sum_{k=0}^{M} \frac{(\lambda_1/\mu_1)^k}{k!}} \right]$$

$$S2 = \frac{1}{M} \sum_{i=0}^{M} i r_i = \frac{a}{M} \left( \frac{\lambda_1}{\mu_1} \right) (1 - r_M)$$

$$S2 = aS1$$

## Numerical result (full rate)



## Conclusions

- From service or user's point of view, blocking probability is most important.
- From network provider's point of view, implementation of less number of traffic channels is always better, because of its higher utilization. Network efficiency is important from economical point of view.
- A general rule (according to our analysis) for base station design is to keep the total number of channels somewhere between 25 and 40.
- The exact amount of free channels can be obtained analytically.

## Questions

# General Packet Radio Services (GPRS)

- Purpose of the chapter
- GSM/GPRS channel structure
- Traffic channel capacity
- Multislot GPRS transmission system
- Numerical Results
  - Scope from discontinuous voice sources
  - Average number of GPRS slots
- Application of this result
- Conclusions

# Purpose of the chapter

- The core network of the third generation mobile communication system will be Global System for Mobile (GSM) based.
- The initial implementation of GSM was for the voice communications.
- IP based data transmission is increasing
- GPRS can support it.
- A proper analytical tool is needed for multislot discontinuous GPRS transmission

# Traffic channel capacity

- Erlang Loss formula is widely used for the analysis of normal telephone networks.

$$p(m) = \frac{(\lambda_1/\mu_1)^m / m!}{\sum_{k=0}^{M} (\lambda_1/\mu_1)^k / k!}$$

$$S1 = \frac{1}{M}\sum_{m=0}^{M} m p(m) = \frac{1}{M}\left(\frac{\lambda_1}{\mu_1}\right)(1 - p(M))$$

$$p(M) = \frac{(\lambda_1/\mu_1)^M / M!}{\sum_{k=0}^{M} (\lambda_1/\mu_1)^k / k!}$$

# Multislot GPRS transmission system

- Multiple number of slots can be occupied by one terminal.
- If maximum *D* GPRS terminals are allowed in a base station, then

$$p(n) = \frac{(\lambda_d/\mu_d)^n / n!}{\sum_{i=0}^{D} (\lambda_d/\mu_d)^i / i!}$$

# Multislot Real-time traffic transmission over GPRS

- One GPRS data terminal can occupy maximum *q* slots.
- Therefore they can occupy maximum *nq* slots from each time frame duration.
- Considering the occupation of each slot is independent with each other and they are occupying each slot with probability *b*.
- Therefore the probability that *k* slots are occupied by *n* data terminals is given by

$$p(k|n) = \binom{nq}{k} b^k (1-b)^{nq-k}$$

# Multislot GPRS transmission system

$$p(k) = \sum_{n=\lceil k/q \rceil}^{D} p(k|n) p(n)$$

- where the value of $\lceil z \rceil$ defines the smallest integer $\geq z$ .
- Finally, the average number of channels is occupied by all GPRS data sources

$$U_D = \sum_{k=0}^{D} k p(k) = (\lambda_d/\mu_d) bq[1 - p(D)]$$

## Average number of GPRS slots

$$U_D = \sum_{k=0}^{Dq} kp(k)$$

$$= \sum_{k=1}^{Dq} k \sum_{n=\lceil k/q \rceil}^{D} p(k|n)p(n)$$

$$= \sum_{k=1}^{Dq} k \sum_{n=\lceil k/q \rceil}^{D} \frac{(\lambda_d/\mu_d)^n/n!}{\sum_{n=0}^{D}(\lambda_d/\mu_d)^n/n!} \binom{nq}{k} b^k (1-b)^{nq-k}$$

$$= (\lambda_d/\mu_d)bq \sum_{k=1}^{Dq} \sum_{n=\lceil k/q \rceil}^{D} \frac{\frac{(\lambda_d/\mu_d)^{n-1}}{(m-1)!}}{\sum_{n=0}^{D}(\lambda_d/\mu_d)^n/n!} \frac{\frac{(nq-1)!}{(nq-k)!(k-1)!}}{1} b^{k-1}(1-a)^{nq-k}$$

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## Average number of GPRS slots

$$n' = n-1$$

$$\Rightarrow (\lambda_d/\mu_d)bq \sum_{k=0}^{(D-1)q} \sum_{n'=\lceil k/q \rceil}^{D-1} \frac{\frac{(\lambda_d/\mu_d)^{n'}}{n'!}}{\sum_{n=0}^{D}(\lambda_d/\mu_d)^n/n!} \frac{\frac{(n'q)!}{(n'q-k)!k!}}{1} b^k (1-b)^{n'q-k}$$

$$= \frac{(\lambda_d/\mu_d)bq}{M}\left[\sum_{k=0}^{Dq} \sum_{n'=\lceil k/q \rceil}^{D} \frac{\frac{(\lambda_d/\mu_d)^{n'}}{n'!}}{\sum_{n=0}^{D}(\lambda_d/\mu_d)^n/n!} \binom{n'q}{k} b^k (1-b)^{n'q-k} - \frac{\frac{(\lambda_d/\mu_d)^D}{M!}}{\sum_{n=0}^{D}\frac{(\lambda_d/\mu_d)^n}{n!}}\right]$$

$$U_D = (\lambda_d/\mu_d)bq[1-p(D)]$$

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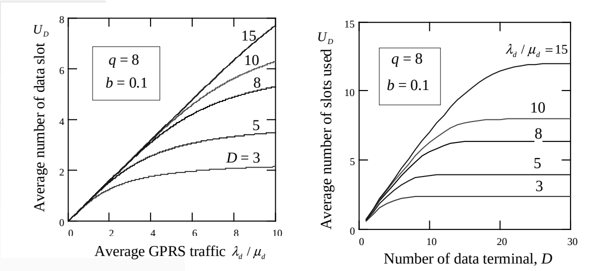
## Average number of GPRS slots



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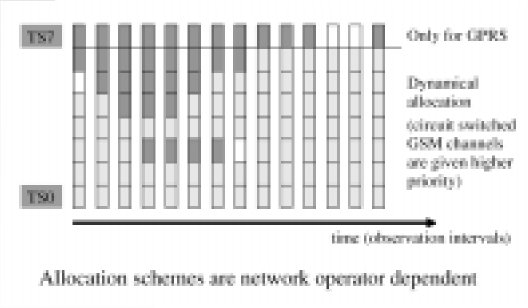
## Application of this result



Allocation schemes are network operator dependent

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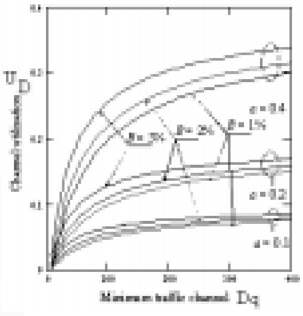
## Real-time over the GPRS is an inefficient process



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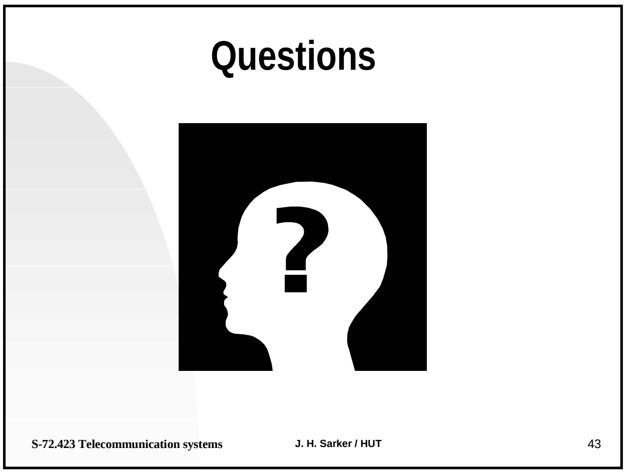
## Conclusions

- The maximum channel utilisation with voice traffic activity is same as the activity factor.
- The channel utilisation can be increased by allowing more GPRS terminals.
- The channel utilisation can be increased with the increase of GPRS traffic intensity.
- The GPRS slot occupancy is directly proportional to the maximum allowed slot per GPRS terminal and the GPRS traffic intensity.
- Multislot real-time traffic is an inefficient process.
- High Speed Circuit Switched Data (HSCSD) might be the solution.



# Questions