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RAN Dimensioning for Wireless Networks

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Abstract – This paper paper will present the general process of radio network design dimensioning and the way the Vamos feature impacts dimensioning of the Radio Access Network. The impact of VAMOS feature over the Abis Interface dimensioning will be described.

Keywords: Abis, Vamos, capacity dimensioning

I. INTRODUCTION

The architecture of a 2G GSM network is presented in Fig.1.

The Radio Access Network (RAN) is composed of the BSC (Base Station Controller), the BTS (Base Transceiver Station), the TC (Transcoder) and the MFS (Multi-BSS Fast Packet Server) [1].

The BTS is a radio equipment which uses the radio interface to receive and transmit information.A group of BTS is handled by one BSC. The interface between the BTS and the BSC is called Abis interface [2].

The BSC handles all associated radio functions like RR management (for radio resource management and mobility management during a call), power control, handover, cell configuration data and channel allocation. A group of BSC is served by a MSC (Mobile Switching Center) and a SGSN (Serving GPRS Service Node). Two interfaces leave the BSC: Ater CS which is the interface conveying CS information towards the transcoder (TC) and Ater PS which is the interface conveying PS information towards the MFS.

The transcoder can handle different types of codecs: FR (Full Rate), EFR (Enhanced Full Rate), HR (Half Rate), AMR (Adaptive Multi Rate, transforms the different coding into A law/miu law coding used in the PCM format) and its major function is to translate the 16 kbps channels called nibbles into 64 kbps channels called time slots (TS). The TC is linked to the MSC by the A interface.

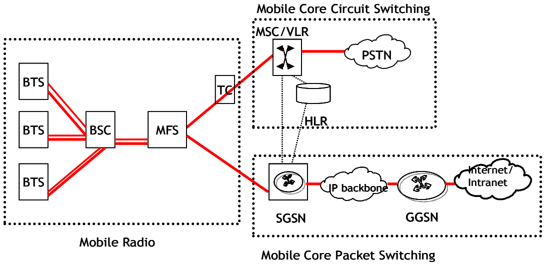

Fig. 1 GSM/GPRS/EDGE architecture[1]

The MFS is in charge of performing the Packet control function through the PCU (Packet Control Unit).

The interface between the MSC and the SGSN is called the Gb interface.

In this paper, the capacity dimensioning for the Abis interface dimensioning for CS traffic coming from IP sites will be detailed.

The capacity analysis is done independently from the coverage analysis. Indeed the capacity of a cell, i.e. the number of subscribers that can be handled, depends only on:

- the user profile,
- the cell characteristics (i.e. how many TRXs are available and in which configuration),
- the radio features that are available to boost the capacity.

Also, it will be presented the impact of the VAMOS feature over the dimensioning process of this interface.

II. VAMOS FEATURE

VAMOS (Voice services over Adaptive Multi-user channels on One Slot) is a 3GPP work item, the objective of which is to specify a way in which two users may be multiplexed on the same radio resource simultaneously, i.e. using the same radio timeslot and physical sub-channel.

In order to be able to use VAMOS, No new traffic channels will be introduced to support VAMOS. The existing FR and HR traffic channels will be used.

A. *Downlink process*

In the downlink direction, the BTS transmits simultaneously to two MSs (Mobile Stations) on the same frequency and TS, but using two different training sequences, and a different modulation scheme – alpha-Quadrature Phase Shift Keying (α -QPSK), presented in “Fig. 2”[6], which allows two users to share the same bandwidth, at the penalty of increased interference.

In the diagram, two users are sharing the same bandwidth, one using the first bit in each symbol, and the other used the second. The value of α is chosen to

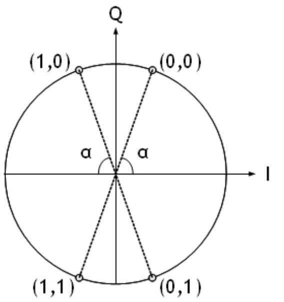

Fig. 2 α -QPSK diagram[7]

allow the power allocated to the two users to be unequal.

α -QPSK can only be used when there is a 2-bit symbol to transmit (one bit from each user). Therefore, when DTX (Discontinuous Transmission) is active, and there is a pause in speech from one user, the other must switch back to using GMSK (Gaussian Minimum Shift Keying, standard modulation scheme) for the duration of the pause.

B. *Uplink process*

In the uplink direction, two MSs simultaneously transmit their GMSK signal to the BTS on the same TS and frequency. The BTS uses the different training sequences to separate the signals (see Table 1).

Table 1 VAMOS Training sequences [6]

Training Sequence	Training sequence bits for the first set
0	(0,0,1,0,0,1,0,1,1,1,0,0,0,0,1,0,0,0,1,0,0,1,0,1,1,1)
1	(0,0,1,0,1,1,0,1,1,1,0,1,1,1,1,0,0,0,1,0,1,1,0,1,1,1)
2	(0,1,0,0,0,0,1,1,1,0,1,1,1,0,1,0,0,1,0,0,0,0,1,1,1,0)
3	(0,1,0,0,0,1,1,1,1,0,1,1,0,1,0,0,0,1,0,0,0,1,1,1,1,0)
4	(0,0,0,1,1,0,1,0,1,1,1,0,0,1,0,0,0,0,0,1,1,0,1,0,1,1)
5	(0,1,0,0,1,1,1,0,1,0,1,1,0,0,0,0,0,1,0,0,1,1,1,0,1,0)
6	(1,0,1,0,0,1,1,1,1,1,0,1,1,0,0,0,1,0,1,0,0,1,1,1,1,1)
7	(1,1,1,0,1,1,1,1,0,0,0,1,0,0,1,0,1,1,1,0,1,1,1,1,0,0)
	Training sequence bits for the second set
0	(0,1,1,0,0,0,1,0,0,0,1,0,0,1,0,0,1,1,1,1,0,1,0,1,1,1)
1	(0,1,0,1,1,1,1,0,1,0,0,1,1,0,1,1,1,0,1,1,1,0,0,0,0,1)
2	(0,1,0,0,0,0,0,1,0,1,1,0,0,0,1,1,1,0,1,1,1,0,1,1,0,0)
3	(0,0,1,0,1,1,0,1,1,1,0,1,1,1,0,0,1,1,1,1,0,1,0,0,0,0)
4	(0,1,1,1,0,1,0,0,1,1,1,1,0,1,0,0,1,1,1,0,1,1,1,1,1,0)
5	(0,1,0,0,0,0,0,1,0,0,1,1,0,1,0,1,0,0,1,1,1,1,0,0,1,1)
6	(0,0,0,1,0,0,0,0,1,1,0,1,0,0,0,0,1,1,0,1,1,1,0,1,0,1)
7	(0,1,0,0,0,1,0,1,1,1,0,0,1,1,1,1,1,1,0,0,1,0,1,0,0,1)

III. BSS IP ARHITECTURES

The Abis interface conveys the CS traffic between the BTS and the BSC. The transport mode that can be used on this interface can be TDM or IP. Since the VAMOS feature is available only with IP in the BSS, only the 2 available IP architectures will be presented:

A. *IP over Ethernet*

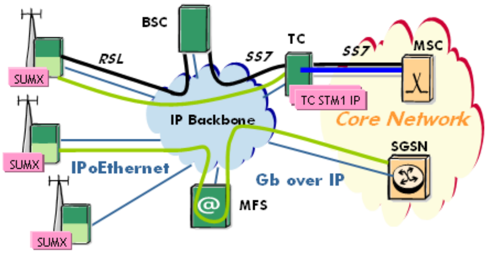

Fig. 3 IPoEth architecture

The first architecture is called IP over Ethernet (IPoEth) and offers a full IP over Ethernet solution. The CS user plane flow that goes directly to the TC and it is called the Abis CS flow. When dimensioning the IP over Ethernet network the peak and the average throughputs need to be computed.

B. *IP over E1*

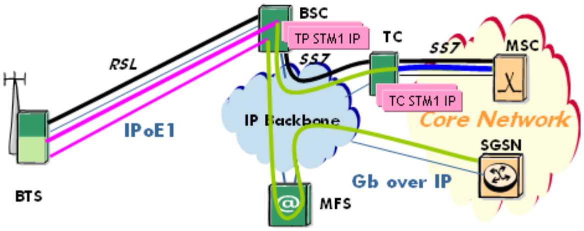

Fig. 4 IPoE1 architecture

The second IP architecture is called IP over E1 (IPoE1). This architecture keeps the existing E1 links on the Abis interface, and then introduces IP transport within these links, using the Point-to-Point Protocol (PPP) or the Multi Link PPP (ML-PPP) in the case of two or more E1 links. The difference compared to the previous architecture is the fact that the whole traffic is routed towards the BSC. Beyond the BSC, the logical flows are conveyed through the IP backbone. The Ater CS flow is going form the BSC to the TC. So, compared to the previous architecture, a new flow appears.

IV. ABIS INTERFACE DIMENSIONING FOR CS

A. *Information packing and headers*

The CS traffic is carried on TRAU (Transcoder and Rate Adaptation Unit) frames. One TRAU frame lasts 20 ms and is carried on the TDMA frames. The 20 ms correspond to the duration of 4 TDMA frames. Looking at the "Fig. 5", it can be observed that a first part of the TRAU frame is carried on TS1 of the 1st

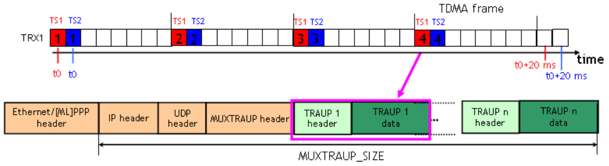

Fig. 5 Multiplexing of TRAUP frames on IP packets

TDMA frame, the second part is carried also on TS1 of the second TDMA frame, the 3rd part of the TRAU frame is carried on TS1 of the 3rd TDMA frame and the last part of the TRAU frame is carried on TS1 of the 4th TDMA frame. Finally, after 4 TDMA frames, the whole TRAU frame is sent. The red TS correspond to the 1st TRAU frame. A second TRAU frame is carried on TS2 of each TDMA frame during 4 TD MA frames lasting 20 ms in the same way as the 1st one. In the figure above, the blue TS correspond to the 2nd TRAU frame [7].

After the full TRAU frame is sent, it is put in an IP packet. The IP packet contains only full TRAU frames, in consequence only after the last part of the TRAU frame has been received, it can be put in an IP packet. Several TRAU frames are multiplexed over IP packets. The TRAUP packets are composed out of some useful information represented in the dark green color and some headers represented in light green. Inside the IP packet there are headers from each protocol used: MUXTRAUP, UDP, IP and depending on the architecture IPoEth or IPoE1 the Ethernet or the [ML] PPP header is added.

When putting TRAUP frames into IP packets one of the two limitations may occur before sending the IP packet:

a) Maximum size supported by the IP packet (MUXTRAUP_SIZE), which does not include the Ethernet or the [ML] PPP header. The typical size is 800 bytes [3].
b) Maximum time elapsed since beginning the sending of TRAUP packets reflected in the timer MAX_HOLD_MUXTRAUP. The default value is 2 ms.

The IP packet is sent when encountering the first limitation. If the delayed timer MAX_HOLD_MUXTRAUP has expired then the packet is sent even if it is not full, i.e. even if it didn't reach the maximum 800 bytes size.

These limitations will be carefully considered when computing the number of IP packets needed to send some information and the overheads associated to it.

The headers for IPoEth and IPoE1 are presented in Table 2.

Table 2 IPoEth and IPoE1 headers [7]

	IPoEth	IPoE1
Header	Size (bytes)	
Ethernet	38	-
[ML]PPP HDLC	-	9 [13]
UDP/IP	28	
MUXTRAUP	2	
TRAUP	Number_of_TRAUP_Frames * TRAUP_Size	
Total (without TRAUP)	68	39 [43]

PPP (Point-to-Point Protocol) HDLC is used in case of a single E1 link on the Abis. In case of 2 or more E1 links, [ML] PPP is used (Multi-link Point-to-Point Protocol).

The TRAUP frame is built up as follows:

UL: 2 bytes (UL Address) + 1 byte (control) + N bytes (payload, incl. 2 or 4 bits for the payload type) [3]

DL: 2 bytes (Call-ID + DL Address) + 1 byte (control) + N bytes (payload, incl. 2 or 4 bits for the payload type) [3]

The payload depends on the codec. The values considered in Alcatel-Lucent's method[3] are:

a) TRAUP_Size FR = 244 bits
b) TRAUP_Size HR = 148 bits

B. *IP Packets:*

Headers associated to IP packets lead to overheads and the number of IP headers depends on the number of IP packets. In order to compute the overheads on Abis introduced by all the protocol headers, the number of IP packets need to be computed first.

The computation of the number of IP packets used to carry CS traffic over 20 ms (TRAU frame duration) depends then on the number of TRAU frames created during T_MAX_HOLD_MUXTRAUP and the maximum size of the IP packet.

The size of the information that can be put in an IP packet during the timer T_MAX_HOLD_MUXTRAUP is computed. This will depend on the TRXs and the TS used for CS.

$$\mathrm{Information}_{\mathrm{size}} = \frac{\mathrm{N}_{\mathrm{CS}}}{8} \times \mathrm{TRAU} \times \mathrm{RoundDown}\left(\frac{\mathrm{T}_{\mathrm{MAX}_{\mathrm{HOLD}_{\mathrm{MUXTRAUP}}}}}{\mathrm{timeslot}_{\mathrm{duration}}}\right) \quad (1)$$

With VAMOS, it is possible to carry 2 calls (i.e. 2 TRAU frames over 20ms) simultaneously on each radio TS.

The number of calls will be doubled for a proportion π_{VAMOS} of the TS, and will remain as previously for a proportion (1- π_{VAMOS}).

Consequently, the number of TRAU frames, and also the number of TRAUP bits, will change by introducing a factor of:

$$(1- \pi_{\mathrm{VAMOS}}) + 2 \times \pi_{\mathrm{VAMOS}} = [1 + \pi_{\mathrm{VAMOS}}] \qquad (2)$$

After the introduction of (2) in (1) we get:

$$Information_{size} = \frac{N_{CS}}{8} \times (1 + \pi_{VAMOS}) \times TRAUP_{bits} \times \mathrm{roundDown}\left(\frac{\mathrm{T}_{\mathrm{MAX}_{\mathrm{HOLD}_{\mathrm{MUXTRAUP}}}}}{\mathrm{timeslot}_{\mathrm{duration}}}\right) \qquad (3)$$

The number of IP packets is the total information to be carried divided by the maximum size of the blocks used to carry that information. Or conversely, the number of TS needed to be carried divided by the number of TS corresponding to the Max_size. The active TS, NCS to be sent are multiplied with the VAMOS factor to account for the fact that with VAMOS 2 calls are simultaneously carried on one TS.

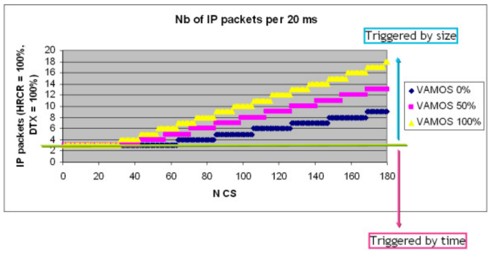

Fig. 6 Number of IP Packets per 20 miliseconds

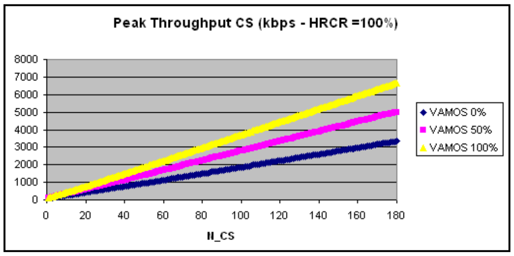

Fig. 7 VAMOS impact on Peak Throughput

The denominator represents the number of TS corresponding to Max_size which is the maximum size divided by the size of the TRAUP frame which takes into account the HRCR and the different values of the TRAUP frame for HR and FR.

$$N_{IP_{packet_{CS}}} = RoundUp\{\frac{N_{CS} \times (1 + \pi_{VAMOS})}{RoundDown\left(\frac{MAX_{Size}}{[HRCR \times 2 \times TRAUP_{Size_{HR}} + (1 - HRCR) \times TRAU_{Size\,HR}]}\right)} \quad (4)$$

C. Peak Throughput

The CS peak throughput is the throughput reached when all the CS radio TS are simultaneously active. By multiplying the number of active TS used for CS by the bitrate per TS, the figure obtained, Fig.7, is the useful throughput for NCS TS.

$$PeakThroughput_{CS} = N_{CS} \times [BitRate_{FR} \times (1 - HRCR) + 2 \times BitRate_{HR} \times HRCRC] \times (1 + \pi_{VAMOS}) \quad (5)$$

As it can be observed in the above chart the Peak throughput increases rapidly with the VAMOS penetration. For instance for a number of 180 active TS the throughput achieved with VAMOS 100% is more than double the one achieved without VAMOS.

D. Peak Overheads

The total CS overheads are computed by including also the TRAUP headers (1 TRAUP header per active call over 20 ms).The number of TRAUP frames in the 20ms period is doubled for the πPAIRED calls.

$$Overhead_{CS} = [N_{IP_{packets_{CS}}} \times IP_{headers} + N_{CS} \times TRAUP_{headers} \times (1 + \pi_{VAMOS}) \times (1 + HRCR)]/20\ ms \quad (6)$$

Although the Peak overheads increase with the VAMOS penetration (Fig. 8) - which is normal considering that the more packets are sent during the reference period, the more headers are sent, thus the larger quantity of OH – the overhead ratio (Fig. 9) computed as the overhead information reported to the useful information tends to the same constant value no matter the VAMOS penetration for large configurations (more than 50 NCS).

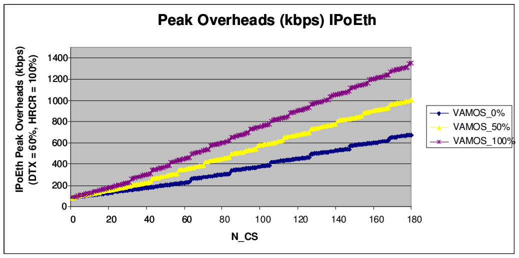

Fig. 8 VAMOS influence on the Peak OH

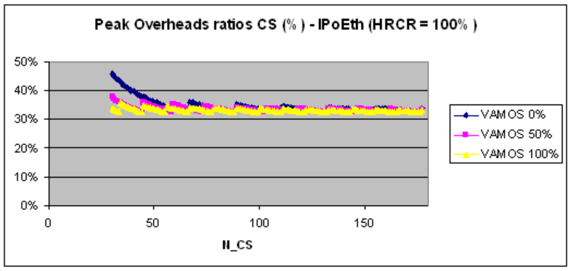

Fig. 9 VAMOS influence on OH ratio

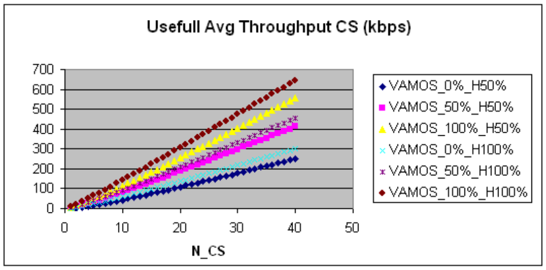

Fig. 10 VAMOS impact on Useful Average Throughput

E. Average Throughput

The Average throughput, Fig.10, is composed out of the useful average throughput and the average overheads. The average OH will be discussed in the next paragraph. The useful average throughput is impacted by the same $[1 + \pi_{VAMOS}]$ factor:

$$UsefulAverageThroughput = [BitRate_{FR} \times (1 - HRCR) + 2 \times BitRate_{HR} \times HRCR] \times (1 + \pi_{VAMOS}) \times (\sum_{cell} \rho\_cell) \quad (7)$$

Where ρ_{cell} represents the traffic intensity in the cell.

In the above charts, apart of the fact that the throughput increases with the VAMOS penetration, it is also that no major gain is brought by passing from 50% HRCR to 100% HRCR for the same penetration of VAMOS (see light blue and dark blue lines), on the other hand a significant improvement can be observed when passing from VAMOS 0% to VAMOS 100% for the same HRCR (see dark blue and pink lines).

Furthermore, the impact on the average throughput is a major one when considering both HRCR and VAMOS 100%, the average throughput more than doubles for the same number of NCS.

F. Average Overhead

For the average overhead computation, all the states in which the system can be must be considered. The following states and their corresponding probabilities of occurrence must be considered: the state with 1 active call, with 2 active calls and so on up to NCS active calls. For one specific state the computation is the same as for the peak, but with NCS replaced by k which can take values from 1 to NCS. The VAMOS impact relies as for the peak in the number of IP packets and the number of TRAUP frames transferred during the 20ms period:

$$Overhead_{CS}(k) = [N_{IP_{packets_{CS}}} \times IP_{headers} + k \times TRAUP_{headers} \times (1 + \pi_{VAMOS}) \times (1 + HRCR)]/20\, ms \qquad (8)$$

An average overhead will be computed taking into account all the overheads introduced by different states and their probability of occurrence:

$$AverageOverhead_{CS} = \sum p(k) \times Overhead_{CS}(k) \qquad (9)$$

Since the average overhead computation is practically based on the same formula as the peak overhead, the same observations are valid, the overhead increases with the NCS and also with the VAMOS proportion. For the overhead ratio, although the overheads start from a higher value for larger VAMOS penetration, after a given configuration in terms of number of active TS, the overhead ratio tends toward a constant value no matter the VAMOS penetration.

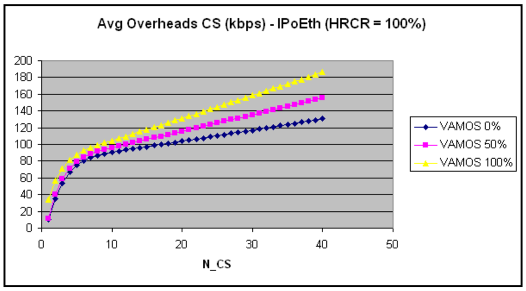

Fig. 11 VAMOS impact on Average Overhead

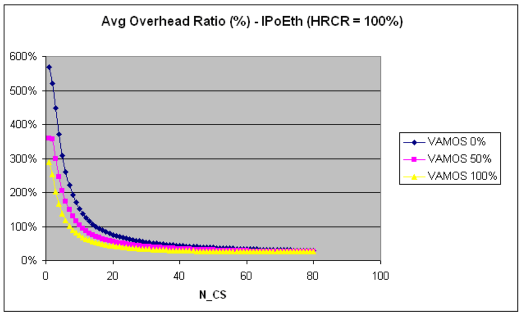

Fig. 12 VAMOS impact on Average Overhead Ratio

V. CONCLUSIONS

VAMOS uses a new modulation, α-QPSK to allow two voice calls to be transmitted simultaneously over the same timeslot. This feature impacts the network design dimensioning process in two of its branches: Capacity and Abis dimensioning. A new parameter is needed to account for the VAMOS impact, π_{VAMOS}.

Abis Dimensioning requires changes to Number of IP Packets computation, peak and average Overhead and Throughput formulas to account for additional traffic present. The influence relies on the $[1 + \pi_{VAMOS}]$ factor which is explained by the fact that with VAMOS, it is possible to carry 2 calls (i.e. 2 TRAU frames over 20ms) simultaneously on each radio TS, thus the number of calls will be doubled for a proportion π_{VAMOS} of the TS, and will remain as previously for a proportion $(1 - \pi_{VAMOS})$.

Consequently, the number of TRAU frames in all the previous formulas used in Abis dimensioning will change by introducing a factor of $(1 - \pi_{VAMOS}) + 2 * \pi_{VAMOS} = [1 + \pi_{VAMOS}]$.

The effects of an increased VAMOS penetration on Abis dimensioning are the increase of number of IP packets that can be sent during the 20 ms period, the increase of average and peak throughput but also the increase of generated overheads which come from the packet headers. All in all VAMOS brings a major improvement since the throughput is larger and the overall overhead ratio tends toward a constant figure no matter the VAMOS penetration for a given number of resources larger than 50 NCS.

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