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| **Agenda item:** | 10 |
| **Source:** | Nokia, Nortel Networks |
| **Title:** | Proposal for a DL slot structure to support EVRC vocoder |
| **Document for:** | Approval |

**Summary:**

As a result of harmonization, there is a need to provide support for the EVRC voice service. In the context of the work of WG1, it is important at this time to identify a potential slot structure within the physical as a “hook” for Release ’99. This contribution discusses the requirements for support of EVRC and identifies 4 potential slot structures that could be included in Release ’99.

# 1. INTRODUCTION

As a result of half a year of harmonization activities, the Operator's Harmonization Group (OHG) agreed on a harmonized Global 3G (G3G) CDMA standard framework [1]. As part of the framework the efficient support of low data rate services (e.g. 8 kbps speech) was identified as a priority. Specificly, this means that it should be possible to use SF=256 on the downlink physical channel for transmission of speech services in order to have a sufficient number of orthogonal codes.

# 2. CHARACTERISTICS OF EVRC TRANSMISSION IN CDMA2000

EVRC is a multi-rate voice codec that supports variable rate transmission of speech based on voice activity. The highest rate of EVRC, the full rate, is 8.55 kbps corresponding to 171 bits every 20 ms. The vocoder produces signals at two other rates: a half rate signal of 4 kbps or 80 bits per 20 ms, and an eigth rate signal of 0.8 kbps or 16 bits per 20 ms. In the provisioning of services, the cdma2000 Fundamental Channel also includes a 1/4 rate signal of 2 kbps or 40 bits per 20 ms, although this rate is not actually used by the vocoder.

With the so-called dim and burst method, higher layer signalling or secondary traffic is time-multiplexed within the same 20 ms frame and sent without loss of speech information. However, such higher layer signalling or secondary traffic is not transmitted when the full rate of EVRC is used but only when lower rates are applied so that the total number of bits never exceeds the 171 bits of the full rate. An extra bit is added, referred to as a mode bit, to the full rate frame to indicate the presence of signalling or secondary traffic. If this mode bit is set, additional bits within the frame define the traffic type (signalling or secondary traffic) and the division between primary traffic (speech) and signalling or secondary traffic. The entire frame is then covered with a CRC and convolutionally encoded. This is summarized below in Table 1 taken from [4]. The transmit rate given in the table is the bit rate after appending a CRC and an 8 bit code tail for the convolutional code. Note also that zero bits in the primary traffic corresponds to blank and burst signalling.

**Table 1: Characteristics of Speech and Signalling/Secondary Traffic Transmission with EVRC.**

| Transmit Rate (bps) | Mixed Mode (MM) | Traffic Type (TT) | Traffic Mode (TM) | Primary Traffic (bits/block) | Signalling Traffic (bits/block) | Secondary Traffic (bits/block) |
|---|---|---|---|---|---|---|
| 9600 | ‘0’ | - | - | 171 | - | - |
| | ‘1’ | ‘0’ | ‘00’ | 80 | 88 | - |
| | ‘1’ | ‘0’ | ‘01’ | 40 | 128 | - |
| | ‘1’ | ‘0’ | ‘10’ | 16 | 152 | - |
| | ‘1’ | ‘0’ | ‘11’ | 0 | 168 | - |
| | ‘1’ | ‘1’ | ‘00’ | 80 | - | 88 |
| | ‘1’ | ‘1’ | ‘01’ | 40 | - | 128 |
| | ‘1’ | ‘1’ | ‘10’ | 16 | - | 152 |
| | ‘1’ | ‘1’ | ‘11’ | 0 | - | 168 |
| 4800 | - | - | - | 80 | - | - |
| 2400 | - | - | - | 40 | - | - |
| 1200 | - | - | - | 16 | - | - |

## 3. EFFICIENT SUPPORT OF EVRC IN UTRAN

There are several possibilities for how EVRC might be supported in UTRAN.

1. It might be possible to perform the multiplexing in the MAC following the procedure described above and use one transport channel for the service. That channel might be seen as a single variable rate channel whose rate could be blindly detected. Our understanding is that this form of multiplexing in the MAC is not currently supported and some discussion with WG2 may be necessary to determine what changes (or “hooks”) might be necessary to support this option.

2. Alternatively, we might remove the mode bit and the traffic type/mode bits and replace these functions by TFCI. The speech and signalling could be on one transport channel with a single CRC or separate transport channels with individual CRCs.

3. A third alternative is to put the speech and signalling onto separate transport channels with individual CRCs and perform blind rate detection (BRD). To be efficient and ensure that the speech service is accommodated at a spreading factor of 256, there needs to be flexibility in the positions that speech and signalling can occupy within the frame rather than the current method of using fixed positions with BRD. To do this, modifications to the blind rate detection algorithm will be necessary to detect the CRC for the speech and then either sequentially or independently detect the CRC for the signalling. If blank and burst signalling is used, an additional means will be needed to indicate whether the detected signal is speech only or signalling only.

The approaches listed above generally assume equal error protection for the speech and the same channel coding for speech and signalling. Unequal error protection for the speech might also be possible and different channel coding for speech and signalling is a further possibility.

The choice of which of these schemes is the most appropriate is beyond the scope of the current discussion and requires further study. The difficulty is that a slot structure needs to be identified that might accommodate any one of these schemes as part of the "hooks and extensions" for Release '99. However, the total number of bits in the frame will change depending on the approach taken and this will influence the amount of puncturing needed for the convolutional code. Also, as part of the harmonization for DS-41, certain parts of the cdma2000 signalling are to be replaced by UTRA signalling and so the number of bits required for this function may change as well. All this complicates the problem of defining a physical layer hook for support of EVRC since the only numbers that can be relied upon at this time are those for the speech signal itself. Having said this, we can make a simplifying assumption that the total number of bits in the DPDCH may not exceed that of the full rate frame plus CRC plus code tail (i.e.,172 + 16 + 8 = 196 bits).

## 4. SLOT STRUCTURE FOR SUPPORT OF EVRC

- With respect to a slot structure that might be used to support EVRC in the physical layer, the most demanding case is in the dowlink due to the limited number of available orthogonal codes. In order to reduce the probability of channelization code shortage (or performance loss due to introduction of additional scrambling codes) it is very desirable to use an SF 256 physical channel.

Currently, the SF 256 downlink physical channel supports only a 15 kbps encoded data rate assuming that no TFCI is used. This is too little for EVRC even if we use r=1/2 convolutional coding. As the dedicated pilot bits consume 40% of all the bits in the slot, a straightforward solution to make more room for data is to reduce the number of pilot symbols. This was naturally identified also in OHG discussions and one of the main discussion items was the question of whether the number of pilot symbols could be reduced to zero.

If we assume that the speech and signalling are multiplexed onto a single transport channel with Equal Error Protection (EEP), a r=1/3 mother code and a CRC of 16 bits, the required amount of puncturing is as shown in Table 2. Tables 3~~4~~ and 4~~6~~ show the amount of puncturing needed if there is a mixture of speech and signalling and 2 TrCHs are used. In Table 3~~4~~ the channel encoding is done separately for the TrCHs whereas in Table 4~~6~~ the use of 1st multiplexing has been assumed.

*Table 2. Example of the amount of puncturing required for EVRC full rate in SF=256 downlink physical channel as a function of number of dedicated pilot symbols per slot. A single CRC = 16 bits and r=1/3 convolutional code have been assumed.*

| | **# of dedicated pilot symbols per slot** | | | |
|---|---|---|---|---|
| | **0** | **2** | **4** | **8** |
| **TFCI=0** | 8 % | 18 % | 29 % | 49 % |
| **TFCI=2** | 18 % | 29 % | 39 % | 59 % |

*Table 3~~4~~. Example of the amount of puncturing required for a mixture of speech and signalling (80 bits speech, 88 bits signalling) in SF=256 downlink physical channel as a function of number of dedicated pilot symbols per slot. Separate TrCHs are used for speech and signalling. CRCs of length 16 bits and no 1st multiplexing possibility has been assumed.*

| | **# of dedicated pilot symbols per slot** | | | |
|---|---|---|---|---|
| | **0** | **2** | **4** | **8** |
| **TFCI=0** | 17 % | 26 % | 35 % | 54 % |
| **TFCI=2** | 26 % | 35 % | 54 % | 63 % |

*Table 4~~6~~. Example of the amount of puncturing required for a mixture of speech and signalling (80 bits speech, 88 bits signalling) in SF=256 downlink physical channel as a function of number of dedicated pilot symbols per slot Separate TrCHs are used for speech and signalling. CRCs of length 16 bits and use of 1st multiplexing has been assumed.*

| | **# of dedicated pilot symbols per slot** | | | |
|---|---|---|---|---|
| | **0** | **2** | **4** | **8** |
| **TFCI=0** | 13 % | 23 % | 33 % | 52 % |
| **TFCI=2** | 23 % | 33 % | 52 % | 62 % |

What is clear is that having 8 pilot bits per slot results in too "heavy" puncturing. With 4 pilot bits we still have too much puncturing if TFCI is used. If BRD is used then required amount of puncturing is around 33-35 % depending on if 1st multiplexing is used or not. That results in a code of about rate ½, which is possible with the current specification. Therefore, the number of pilot bits could be 0, 2 or 4. As pilot bits are used for variety of purposes we need to differentiate at least between cases which do not use Tx diversity and cases where Tx diversity is utilized.

### 4.1 Non-Tx diversity case

In normal operation with no Tx diversity transmission we can use the CPICH for channel estimation. Thus, shortening the dedicated pilot does not affect the channel estimation accuracy and therefore even zero pilot could be used. Unfortunately, fast Transmission Power Control (TPC) needs some energy from the dedicated channel for SIR estimation. As a minimum, we always have 2 TPC bits which can be used to estimate the signal power, however, using these TPC bits alone has been shown [3] to provide quite poor estimates that deteriorate the TPC performance. Consequently, we should have more bits for SIR estimation.

As EVRC is a variable rate codec we need to use either BRD or TFCI to detect the rate. If TFCI is used we have an additional 2 bits per slot which could be used for SIR estimation purposes. Alternatively, we could add two pilot bits and use BRD resulting in same overhead and performance. As such even 4 pilot bits can be added but then the overhead starts to increase, and especially at Voice Activity Factor (VAF) of 50 % better SIR estimation may not outweight the loss due to overhead.

So we have got basically two choices for DPCCH bits per slot in case of SF=256:

- TPC=2, TFCI=2, Pilot=0
- TPC=2, TFCI=0, Pilot=2

Regarding the closed loop power control there is one more additional fact that needs to be taken into account. The current UL/DL frame/slot structure has been carefully designed so that we can have 1 slot TPC loop delay for as large cell radius as possible. Moreover, the processing times at UE and Node B have been carefully balanced. This design assumes that estimation of signal power is based on dedicated pilot symbols. However, as noted above for the case of using TPC bits alone, having only two pilot bits for SIR estimation will result in poor performance. Thus, we propose that the option of having at least one dedicated pilot symbol should be selected and that some consideration be given to using all of the bits in the DPCCH for SIR estimation.

Note that if there is no TFCI we have to use BRD. If the speech and signalling are multiplexed in the MAC and the mode bit method discussed above is used, then the BRD simply has to determine the rate of a single signal. If separate transport channels and CRCs are used for speech and signalling, then flexible transport block positions should be allowed to efficiently fit the speech and signalling into a single frame with spreading factor 256. The current method of using fixed positions and allocating resources as the sum of the maximum rates for the two transport channels. This means that resources to transmit potentially 2 x 171 = 342 bits would have to be allocated if both ‘dim and burst’ and ‘blank and burst’ signalling are utilized. Obviously, this could not be done at a spreading factor of 256 as the maximum number of coded bits allowed is 300.

The use of BRD with flexible positions does not represent a significant problem as the number of rates for the EVRC codec is relatively small. It is fairly straightforward to detect first the speech and once the CRC has been found, the number of bits in the signalling field should be known. The CRC for the signalling is then easily found and verified.Alternatively, BRD of speech and signaling can be done independently of each other by reversing the order of e.g. signaling bits in a frame and starting the BRD from both ends of the frame.

### 4.2 Tx diversity case

If Tx diversity with feedback is used, dedicated pilot bits are used for antenna verification. They may be used for the same purpose in closed loop modes 2 and 3 as well but that issue is still a bit open in Ad Hoc #6.

In order to be able to do verification, dedicated pilot sequences from the antennas should be orthogonal. This implies that as a minimum, we need 2 pilot symbols (4 pilot bits). Therefore, both 2 and 4 pilot bits should be allowed for support of Tx diversity. In case of 4 pilot bits 29% puncturing of the r=1/3 code is needed. That amount of puncturing will result in some performance loss but use of verification will, in turn, improve the performance.

## 4.3 Summary of proposal

In order to effectively support the EVRC vocoder in UTRAN the structure of the DPCCH of the downlink physical channel having SF=256 should be modified. The proposal is to have the following structures:

1. TPC=2, TFCI=0, Pilot=2
2. TPC=2, TFCI=2, Pilot=2
3. TPC=2, TFCI=0, Pilot=4
4. TPC=2, TFCI=2, Pilot=4

The fourth option can not be used with full rate EVRC but we should not rule it out as there may be a need to support even lower rate traffic. Note also that flexible use of TFCI already exists in the specification.

The exact method of multiplexing speech and signalling must still be defined and this will have some impact on the efficiency and which of the above slot structures is the most appropriate.

# 5. TEXT PROPOSAL

The text proposal to accommodate the new slot structures is fairly straighforward, it requires modifications to Table 9 of 25.211 and additional text for the discussion of blind rate detection. The modified table is shown below with the changes highlighted in bold.

-----------------------------text proposal for 25.211, Section 5.3.2-------------------------------------

**Table 9: DPDCH and DPCCH fields**

| Channel Bit Rate (kbps) | Channel Symbol Rate (ksps) | SF | Bits/Frame | | | Bits/ Slot | DPDCH Bits/Slot | | DPCCH Bits/Slot | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | DPDCH | DPCCH | TOT | | $N_{Data}$ | $N_{Data}$ | $N_{TF}$ | $N_{TP}$ | $N_{Pil}$ |
| 15 | 7.5 | 512 | 60 | 90 | 150 | 10 | 2 | 2 | 0 | 2 | 4 |
| 15 | 7.5 | 512 | 30 | 120 | 150 | 10 | 0 | 2 | 2 | 2 | 4 |
| **30** | **15** | **256** | **240** | **60** | **300** | **20** | **0** | **16** | **2** | **0** | **2** |
| **30** | **15** | **256** | **240** | **60** | **300** | **20** | **0** | **16** | **2** | **2** | **2** |
| **30** | **15** | **256** | **210** | **90** | **300** | **20** | **0** | **14** | **2** | **0** | **4** |
| **30** | **15** | **256** | **210** | **90** | **300** | **20** | **0** | **14** | **2** | **2** | **4** |
| 30 | 15 | 256 | 150 | 150 | 300 | 20 | 2 | 8 | 0 | 2 | 8 |
| 30 | 15 | 256 | 120 | 180 | 300 | 20 | 0 | 8 | 2 | 2 | 8 |
| 60 | 30 | 128 | 450 | 150 | 600 | 40 | 6 | 24 | 0 | 2 | 8 |
| 60 | 30 | 128 | 420 | 180 | 600 | 40 | 4 | 24 | 2 | 2 | 8 |
| 120 | 60 | 64 | 900 | 300 | 1200 | 80 | 4 | 56 | 8* | 4 | 8 |
| 240 | 120 | 32 | 2100 | 300 | 2400 | 160 | 20 | 120 | 8* | 4 | 8 |
| 480 | 240 | 16 | 4320 | 480 | 4800 | 320 | 48 | 240 | 8* | 8 | 16 |
| 960 | 480 | 8 | 9120 | 480 | 9600 | 640 | 112 | 496 | 8* | 8 | 16 |
| 1920 | 960 | 4 | 18720 | 480 | 19200 | 1280 | 240 | 1008 | 8* | 8 | 16 |

* If no TFCI, then the TFCI field is blank.

A text proposal for 25.212 on blind rate detection with flexible positions is under development and will be provided before the end of WG1#7. The feasibility of such a scheme has already been elaborated e.g. in [5].

## 6. CONCLUSIONS

Methods for the support of the EVRC vocoder as a result of harmonization have been presented. The exact method as to how the service is to be supported by UTRAN is for further study, however, potential slot structures have been identified for SF=256 and a text proposal included. Blind rate detection with flexible positions is known to be feasible and a text proposal for 25.212 is under development.

REFERENCES

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[23] Nortel Networks and Nokia. Requirements for the support of the EVRC vocoder in UTRA. UTRA L123 Hooks and Extensions Workshop document, WHE(99)027, 24-26th, August, 1999, Sophia Antipolis, France, 2 pp.

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[5] Nortel Networks. A modified Blind rate detection scheme for improved mapping of some transport format combinations, TSG-R WG1 document, TSGR1#6(99)867, July 13th – 16th, 1999, Espoo, Finland.