3GPP TSG-SA3 Meeting #34 **Tdoc S3-040630**
Acapulco, Mexico, 6th – 9th July 2004.

Title: [DRAFT] LS on VGCS: length of VSTK_RAND
Response to:
Release: R6
Work Item: Key Management of group keys for Voice Group Call Services

Source: SA3
To: TSG-GERAN2
Cc:

Contact Person:
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Attachments: S3-040638_Approved 624_CR 43.020_complete_CR_36-bit.doc

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1. Overall Description:

Based on the LS by SAGE (S3-040471 – GP-041716) SA3 has made the following decisions:

a) The length of CELL_GLOBAL_COUNT is 2 bits
b) VSTK_RAND has a length of 36 bit. SA3 would be eager to increase the VSTK_RAND length to 38 bits, if GERAN could accommodate 38 bits (+2 bits for CELL_GLOBAL_COUNT). This would multiply the amount of keys VSTK that can be generated from one V_Ki by a factor 4 and prolong the lifetime of V_Ki accordingly.
c) An informal section on how to avoid VSTK_RAND collisions during the lifetime of V_Ki is included in the specification.
d) The key modification function KMF is based on SHA-1.

The attached CR (S3-040638) reflects these decisions and has been agreed by SA3. It will be forwarded to TSG-SA for approval but will be withdrawn if GERAN2 indicates that at least 36 bits for VSTK_RAND and 2 bits for CELL_GLOBAL_COUNT cannot be provided. Despite of the fact that the attached CR is written with a 36 bits VSTK_RAND, SA3 would appreciate it very much if GERAN2 could provide more bits since it would provide a significantly longer lifetime of V_Ki.

2. Actions:

To GERAN2 group.

ACTION: SA3 ask GERAN2 to indicate as early as possible and well before the next TSG SA#25 (13th – 16th September 2004, Palm Springs, USA) to the chairman of SA3 (Valtteri Niemi, valtteri.niemi@nokia.com) if it is not possible to provide the space for the information elements VSTK_RAND (at least 36 bits) and CELL_GLOBAL_COUNT (2 bits) on the air-interface.

3. Date of Next TSG-SA3 and TSG-SA Meetings:

TSG-SA3 Meeting #35	5th – 8th October 2004	Malta
TSG-SA3 Meeting #36	23rd – 26th November 2004	Shenzhen, China
TSG-SA Meeting #25	13th – 16th September 2004	Palm Springs, USA
TSG SA Meeting #26	13th – 16th December 2004	Athens, Greece

CR-Form-v7

CHANGE REQUEST

⌘ **43.020** **CR** **CRNum** ⌘ **rev** **-** ⌘ Current version: **5.0.0** ⌘

*For **HELP** on using this form, see bottom of this page or look at the pop-up text over the ⌘ symbols.*

Proposed change affects: UICC apps⌘ [X] ME [X] Radio Access Network [X] Core Network [X]

Title:	⌘	Introducing VGCS/VBS ciphering
Source:	⌘	Siemens, Vodafone
Work item code:	⌘	SECGKYV ***Date:*** ⌘ 28/06/2004
Category:	⌘	**B** ***Release:*** ⌘ Rel-6

Use one of the following categories:
F *(correction)*
A *(corresponds to a correction in an earlier release)*
B *(addition of feature),*
C *(functional modification of feature)*
D *(editorial modification)*
Detailed explanations of the above categories can be found in 3GPP TR 21.900.

Use one of the following releases:

2	*(GSM Phase 2)*
R96	*(Release 1996)*
R97	*(Release 1997)*
R98	*(Release 1998)*
R99	*(Release 1999)*
Rel-4	*(Release 4)*
Rel-5	*(Release 5)*
Rel-6	*(Release 6)*

Reason for change:	⌘	Introducing a new feature VGCS/VBS ciphering
Summary of change:	⌘	The new ciphering feature is introduced into Annex F
Consequences if not approved:	⌘	The feature cannot be realized

Clauses affected:	⌘	New Annex F

		Y	N			
Other specs affected:	⌘	Y		Other core specifications	⌘	31.102, 42.068, 43.068, 42.069, 43.069, 44.018, 48.008, 29.002
			N	Test specifications		
			N	O&M Specifications		

Other comments:	⌘	

Annex F (normative): Ciphering of Voice Group Call Service (VGCS) and Voice Broadcast Service (VBS)

This Annex defines the security related service and functions for VGCS and VBS in order to provide confidentiality protection to the group calls.

F.1 Introduction

F.1.1 Scope

In this Annex the ciphering of the voice group call service (VGCS) [1] and voice broadcast service (VBS) [4] is described. The following functions are required:

- Key derivation
- Encryption of voice group/broadcast calls
- The secure storage of the master group keys

VGCS and VBS provide no authentication functions, i.e. authentication is performed implicitly via encryption/decryption since only a legitimate subscriber shall be able to encrypt and decrypt the VGCS/VBS speech call when the group call requires confidentiality protection. To include a subscriber into a voice group the required group data (including the 2 master group keys) shall be stored on the USIM, e.g. during the personalisation process or via OTA (over-the-air). To exclude a subscriber from a voice group the group data shall be deleted from the USIM. In case of a stolen or lost USIM, all USIMs of the remaining members of the voice groups that the USIM is a member of, need to be changed (e.g. via OTA or manual provisioning).

A pre-Rel-6 VGCS/VBS capable mobile shall be able to participate in an un-ciphered group call, if it is part of that group.

NOTE: The only security relevant difference between VBS and VGCS is that in the case of VBS there exists no uplink channel.

F.1.2 References

[1] 3G TS 42.068: 3rd Generation Partnership Project; Technical Specification Group Services and system Aspects; Voice Group Call Service (VGCS) - Stage 1

[2] 3G TS 43.068: 3rd Generation Partnership Project; Technical Specification Group Services and system Aspects; Voice Group Call Service (VGCS) - Stage 2

[3] 3G TS 31.102: 3rd Generation Partnership Project; Technical Specification Group Terminals; Characteristics of the USIM application

[4] 3G TS 42.069: 3rd Generation Partnership Project; Technical Specification Group Services and system Aspects; Voice Broadcast Service (VBS) - Stage 1

[5] 3G TS 43.069: 3rd Generation Partnership Project; Technical Specification Group Services and system Aspects; Voice Broadcast Service (VBS) - Stage 2

[6] 3G TS 23.003: 3rd Generation Partnership Project; Technical Specification Group Core Network; Numbering, addressing and identification

[7] FIPS PUB 180-1 Secure Hash Standard

F.1.3 Definitions and Abbreviations

F.1.3.1 Definitions

A5_Id Identifier of the encryption algorithm which shall be used.
CELL_GLOBAL_COUNT: A counter valid for all voice group calls within a cell.
Group_Id Unique identifier of a voice call group.
KMF Key Modification Function. KMF derives from the short term key VSTK, the CGI and the CELL_GLOBAL_COUNT the cipher key V_Kc which is valid for that specific cell.
VSTK Short Term Key provided by the USIM and the GCR. VSTK is derived from VSTK_RAND and V_Ki (128 bit)
VK_Id Identifier of the Master Group Key (1 bit) of a group. There are up to 2 V_Ki per group
VSTK_RAND The 36-bit value that is used for derivation of a short term key VSTK.
V_Ki (Group_Id, i) Voice Group or Broadcast Group Key (128 bit) number i::=VK_Id of group with Group_Id. In short also called Master Group Key or Group Key in this Annex
V_Kc Voice Group or Broadcast Ciphering Key (128 bit). V_Kc is derived from VSTK

F.1.3.2 Abbreviations

The following list describes the abbreviations and acronyms used in this Annex.

CGI Cell Global Identifier
GCR Group Call Register
VBS Voice Broadcast Service
VGCS Voice Group Call Service

F.2 Security Requirements

The ciphering concept for VGCS, VBS fulfils following security requirements

REQ-1. Prevent the same Voice group or Broadcast group ciphering key being used within different cells.

This requirement protects an observer of getting more information on the plaintext if different data is enciphered with the same key and COUNT (TDMA-numbers derived) in different cells.

REQ-2. The master group key shall never leave the USIM and the GCR.

Even though VGCS/VBS users should be trusted, this approach protects the 'root'-key (I.e. Master Group key) in the most secure way such that it need not be updated very frequently.

REQ-3. Prevent the reuse of COUNT with the same voice group or broadcast group ciphering key within the same cell.

The COUNT value is determined by the TDMA frame number. An overflow happens after each 3 hour and 8 minutes period. The lifetime of the used cipher key shall not be longer than the overflow period.

NOTE: This enhancement goes beyond the provided level of security of GSM-calls over a point to point channel (i.e. is not a VGCS/VBS-problem only) as long standing calls over a dedicated channel have the same characteristic of reusing the COUNT.

REQ-4. Prevent the same key stream block being used in uplink and downlink direction.

This requirement is fulfilled by Point to Point voice calls already (See Annex C.1.2). By reusing the same mechanisms for uplink/downlink key stream derivation (I.e. reusing A5) the VBS/VGCS ciphering also fulfils this requirement.

F.3 Storage of the Master Group Keys and overview of flows

The master group keys (in short called group keys in this Annex) are securely stored at two locations

- GCR: Beside other information, the GCR stores for each Group_Id a list of group keys. Each group key is uniquely identified by the Group_Id and the group key number VK_Id (1-2).
- USIM: The USIM contains a list of 2 group keys for each Group_Id. Deletion or changing of group keys are allowed only via OTA or via USIM-personalisation.

The Short Term Key VSTK shall be deleted by the network entities after tearing down the call and by the ME on power down or UICC removal. On each new VGCS/VBS call set up, a new short term key VSTK shall be generated.

The following sequence gives an overview of how the different network entities make use of the group keys (and derived information) during the establishment of a voice group/broadcast call.

1. During the voice group/broadcast call set-up the anchor-MSC sends a GCR Interrogation to the GCR containing the Group_Id.
2. The GCR provides on the basis of a fresh number VSTK_RAND (see Annex F.7) the key VSTK as described in Annex F.4. VK_Id, VSTK_RAND, VSTK, the permitted ciphering algorithm (A5_Id) and other voice group/broadcast call related information, are sent from the GCR back to the anchor-MSC.
3. The anchor-MSC sends this information to the relay-MSC's via a MAP-operation.
4. The anchor MSC and relay-MSC's sends this information to the BSS using the VGCS Assignment Request or VBS Assignment Request.
5. The BSS sends the CELL_GLOBAL_COUNT, VSTK_RAND, Group_Id and the group key number VK_Id to the ME's via a notification procedure. .
6. Each ME generates the VSTK, on the basis of the received information from step 5, as described in Annex F.4.

A late entrant belonging to the right Group_Id in a cell where a call is active need to pick out the notification parameters from step 5 and executes step 6.

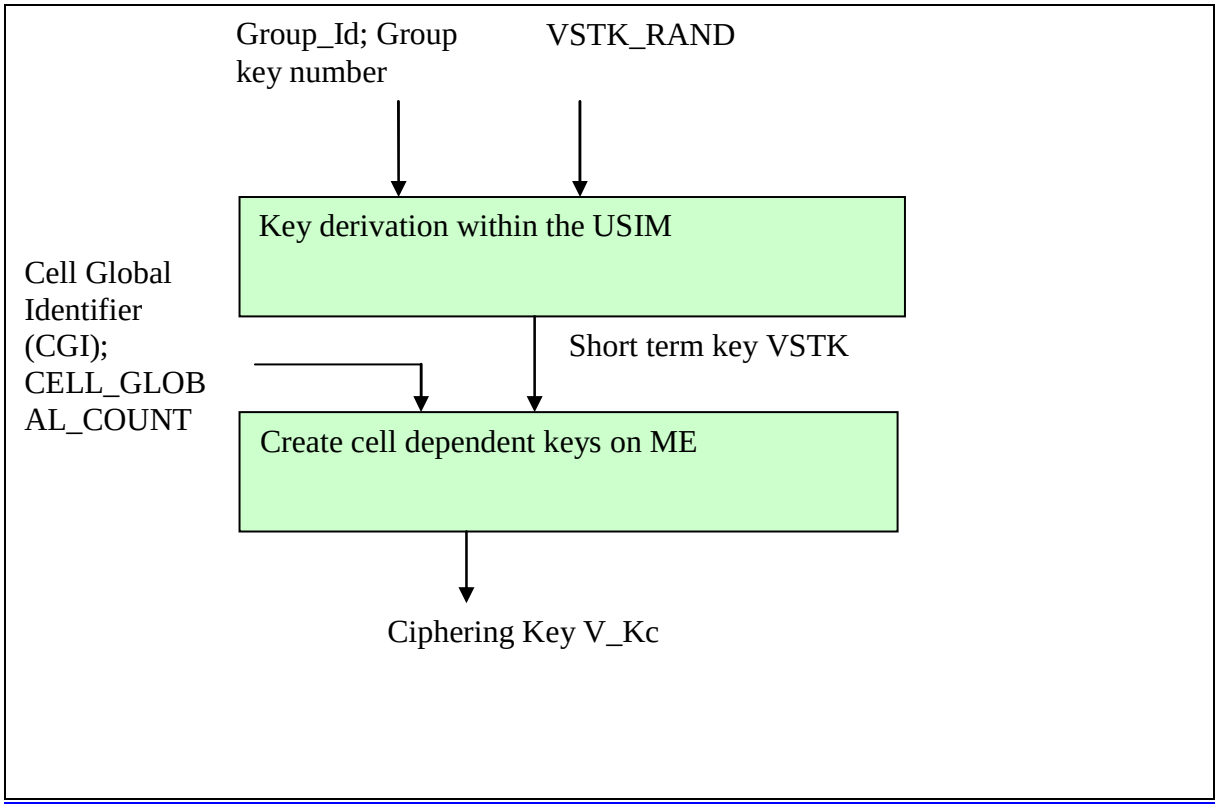
In case of inter-MSC Handover of the talking subscriber the Group_Id, VSTK_RAND, VSTK and A5_Id need to be transferred via MAP Prepare Handover request message from MSC-A to MSC-B.

F.4 Key derivation

The key derivation of the encryption is performed in two steps.

1. Derivation of a short term key VSTK on the GCR-side and USIM; VSTK_RAND generation on the GCR-side and sending it to the ME via the BSS for use on the USIM.

2. Derivation of the actual encryption key V_Kc in the BSS and ME.



F.4.1 Key derivation within the USIM / GCR

This function is performed on

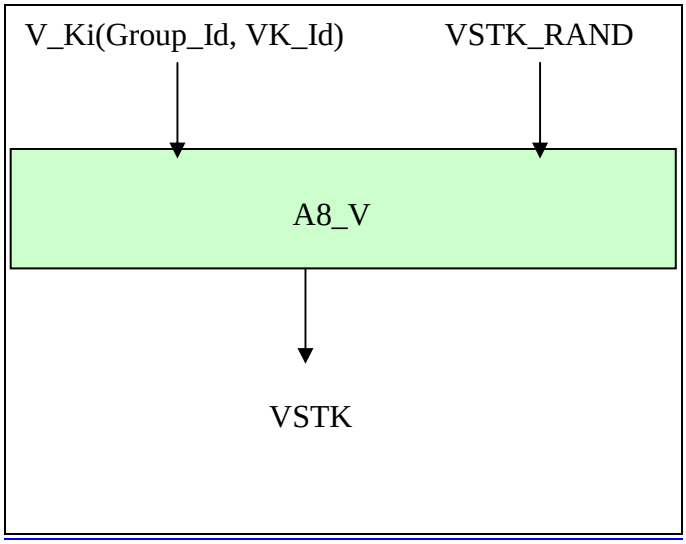
- the set-up of a voice group or broadcast call by the GCR
- entry to a voice group or broadcast call by the USIM

On the set-up of a voice group/broadcast call the GCR generates the VSTK_RAND (See Annex F.7). Also an appropriate group key V_Ki (identified by VK_Id) is selected by the GCR. Using the function A8_V a short term key VSTK is derived using as input parameters:

- V_Ki (Group_Id , VK_Id)
- VSTK_RAND

Output of A8_V is

- VSTK



The GCR sends the parameters Group_Id, VK_Id, VSTK_RAND, VSTK, A5_Id via the anchor-MSC and the relay-MSC's to the BSS. The BSS signals the Group_Id, VSTK_RAND and VK_Id to the ME.

On the ME-side, each ME sends the Group_Id of the voice group or broadcast call, the identifier of the key VK_ID and the VSTK_RAND to the USIM. The USIM performs the calculation of the short term key VSTK using the function A8_V and returns it (together with the encryption algorithm identifier A5_Id).

F.4.2 Key derivation within the ME/BSS

This function is performed on

- Entry to a voice group/broadcast call
- Cell reselection
- Changing of the value of CELL_GLOBAL_COUNT
- Handover

by the ME.

On the network side the function is performed on

- Set-up of a voice group/broadcast call in a cell
- Changing of the value of CELL_GLOBAL_COUNT

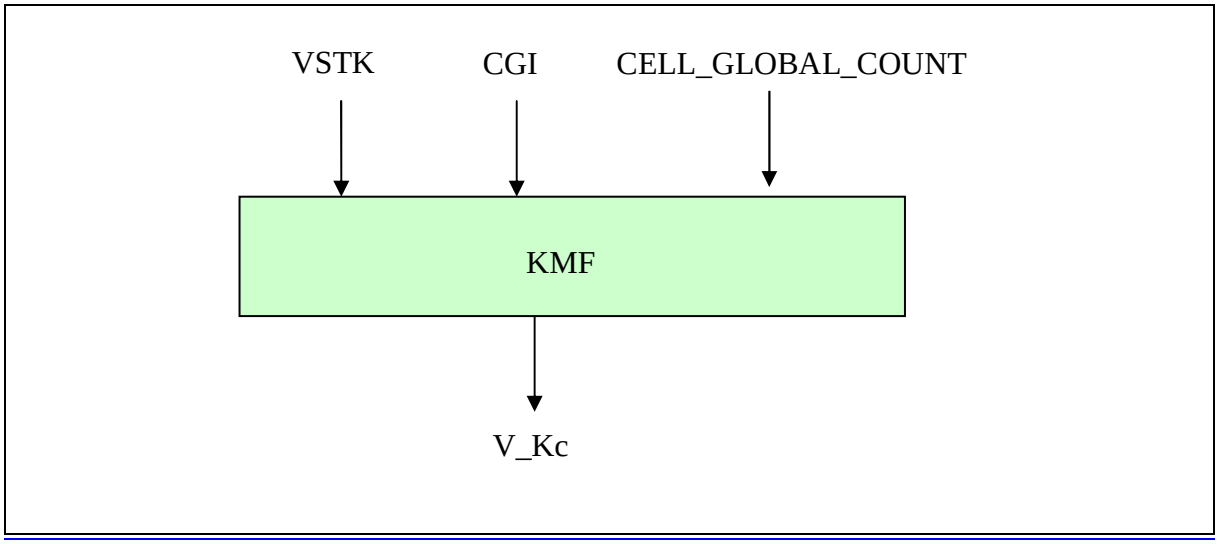
by the BSS.

For each cell the BSS and ME calculate an encryption key V_Kc using the key modification function KMF. Input parameter of the KMF are:

- VSTK: the short term key for this voice call group and this call
- CGI: the cell global identifier which identifies a cell world-wide uniquely.
- CELL_GLOBAL_COUNT: this parameter shall be incremented by the BSS when the TDMA-frame-number wraps around.

NOTE: The MS and network SHALL be aligned regarding the value of the CELL_GLOBAL_COUNT. In case of transmissions on the FACCH, this requires that the network transmits a part of the whole of the TDMA frame number together with the CELL_GLOBAL_COUNT

The output of the key modification function is the actually cipher key V_Kc.



To provide the required information to the ME the parameters CELL_GLOBAL_COUNT and CGI are included in various messages from the BSS to the ME (I.e. CELL_GLOBAL_COUNT on the NCH, FACCH and PCH, and the CGI on the BCCH and the FACCH).

F.4.3 Encryption algorithm selection

The encryption algorithm identifier A5_Id is stored in the GCR and the USIM. For each group key V_Ki(Group_Id, i) there is a unique A5_Id.

A5_Id is transmitted from the GCR to the BSS. The ME fetches the A5_Id together with the VSTK from the USIM.

NOTE: It is possible that different algorithm identifiers are bound to different V_Ki of the same group.

NOTE: The algorithm identifier A5_Id stored in the GCR and on the USIM shall match with the encryption capabilities of the ME's used by the group and the BSS where the voice group calls are allowed to take place.

F.4.4 Algorithm requirements

F.4.3.1 A8_V

The key derivation function A8_V has the following input and output parameter:

Input Parameter:

VSTK_RAND: 36 bit value (See Annex F.7)

V_Ki (Group_Id, i): 128 bit secret key

Output:

VSTK: 128 bit short term key

A8_V is an operator specific algorithm. The calculation time for A8_V shall not exceed 500 ms.

A8_V is implemented in the GCR and on the USIM

F.4.3.1 KMF

The key derivation function KMF has the following input and output parameter:

Input Parameter:

VSTK: 128 bit short term key

CGI: the cell global identifier: 56 bit ([6] TS 23.003)

CELL_GLOBAL_COUNT: 2 bit

Output:

V_Kc 128 bit encryption key

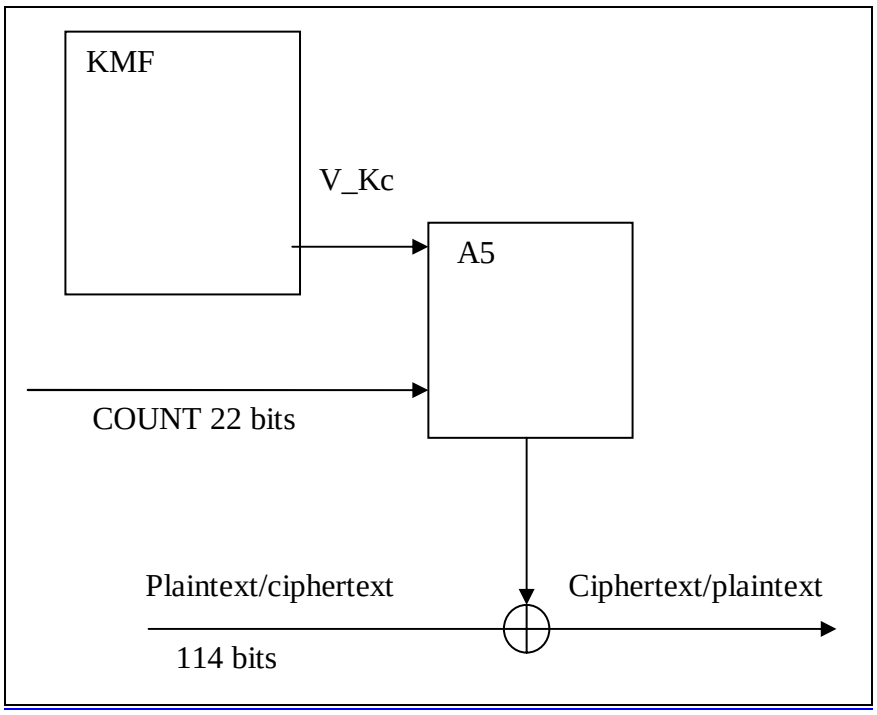
The KMF is implemented in the BSS and in the ME.

The specification of KMF can be found in Annex F.6

F.5 Encryption of voice group calls

For the encryption of a voice group call the same encryption algorithms are used as for a normal GSM speech call. Which algorithm out of the algorithm suite A5/x is used is determined by the identifier A5_Id, which is stored on the USIM (together with the group key V_Ki(Group_Id, i)). The algorithm A5/X is used in the same way as in the GSM (ref. Annex C.1) using the key V_Kc as encryption/decryption key Kc as input to A5/x.

If the key length KL of the encryption algorithm A5/X is shorter than the length of V_Kc (128 bit) then only the KL least-significant KL-bits of V_Kc are used.



F.6 Specification of the Key Modification Function (KMF)

SHA-1 [7] is used for generating V_Kc:

V_Kc= SHA-1(VSTK | CGI | CELL_GLOBAL_COUNT | VSTK)

From the 160-bit output of SHA-1, the 128 bit least significant bits are taken as 128-bit V_Kc.

F.7 Generation of VSTK_RAND (informative)

Since the length of VSTK_RAND (36 bits) is small, care should be taken that a VSTK_RAND isn't generated twice (so-called collision) during the lifetime of V_Ki. On the other hand, the predictibility of VSTK_RAND shall be avoided. The following scheme could be used in order to generate 4096 VSTK_RAND for each V_Ki with a probability < 10^{-6} that a collision occurs:

NOTE: A collision probability of <10^{-4} could still give a sufficient security margin and may allow, depending on the VSTK_RAND structure that is chosen, that more VSTK can be generated from one V_Ki.

The GCR maintains a COUNTER (12 bits) for each voice group. After each generation of a VSTK_RAND for a specific voice group, COUNTER for that voice group is incremented by one.

The left most 12 bits (COUNTER) of VSTK_RAND are set to COUNTER. The remaining 24 bits (RANDOM) are generated randomly, i.e. unpredictably for each new VSTK_RAND.

Therefore VSTK_RAND = COUNTER | RANDOM.

NOTE: The length of RANDOM shall be at least 24 bits.

If COUNTER wraps around, a new V_Ki is required for that group.

Following table gives the maximum number of voice group calls that are possible with a with a full random generated VSTK_RAND

Length of VSTK_RAND	Max collision prob for fixed V_Ki	Number of calls
36	10^{-6}	TBD
36	10^{-4}	TBD

Following table give the maximum number of voice group calls that are possible with a VSTK_RAND as structured in this informative Annex.

Total challenge length	Length of counter	Length of random part	Max collision prob for fixed V_Ki	Max collision prob for one fixed counter	Number of calls for one fixed counter	Total number of calls for fixed V_Ki
36	14	24	10^{-6}	6.10×10^{-11}	1	4096
36	14	24	10^{-4}	6.10×10^{-9}	1	4096