Note: Within nine months of the publication of the mention of the grant of the European patent in the European Patent Bulletin, any person may give notice to the European Patent Office of opposition to that patent, in accordance with the Implementing Regulations. Notice of opposition shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).
FIELD OF THE INVENTION

[0001] The present invention relates to a method for communicating between a primary station and a plurality of secondary stations, and to the corresponding stations.

[0002] This invention is, for example, relevant for telecommunication systems like a mobile telecommunication system. More specifically, this invention is relevant for the UMTS.

BACKGROUND OF THE INVENTION

[0003] In a conventional UMTS system, a PDCCH (Physical Downlink Control Channel) message can use 1, 2, 4 or 8 Channel Control Elements (CCEs or resource elements) - referred to as CCE aggregation levels 1, 2, 4 or 8. A search space is a set of aggregated CCEs (with a certain aggregation level) within which a mobile station (or user equipment (UE) or secondary station) performs blind decoding of all PDCCH payloads possible for that aggregation level. Search spaces are defined per aggregation level; a secondary station in such a system thus can have up to four search spaces. For example, the search space of a UE for aggregation level 1 (referred to as 1-CCE) could consist of the CCEs indexed 3,4,5,6,7,8, while its search space for aggregation level 8 could consist of the two resource sets of aggregated CCEs consisting of the CCEs indexed by 1,2,...,8 and 9,10,...,16, respectively. In this example, the UE thus performs six blind decodings for 1-CCEs and two blind decodings for 8-CCEs.

[0004] In an example, in order to determine the starting point of the search space, mobile stations (or secondary stations, also termed as UEs, for User Equipments in 3GPP parlance) compute a hash function f(UE_ID,s), where UE_ID is the identifier of the UE (different for distinct UEs) and s a time-varying subframe number. It is desirable that different UEs collide (have equal hash value) as infrequently as possible.

[0005] The hash function presently proposed within 3GPP is of the form

\[ f(\text{UE\_ID},s) = K(\text{UE\_ID} \ast 16+s) + L \text{ modulo } M, \]

where K,L and M are constants, UE ID is the identifier of the UE, and s is the subframe number. It is clear that with this particular hash function f, two UEs that collide for some subframe number collide persistently, i.e., for all subframe numbers.

[0006] TSG-RAN WG1 # 52 R1-080869 and 3GPP TSG RAN1 # 50 R1-073373 both disclose the principle of determining the search space of a secondary station on the basis of a hash function.

SUMMARY OF THE INVENTION

[0007] It is an object of the invention to propose a method and corresponding stations for communicating which permits the probability of collisions to be reduced.

[0008] Another object of the invention is to provide a method and corresponding stations for communicating preventing two UEs from repeatedly colliding.

[0009] To this end, according to a first aspect of the invention, a method is proposed for communicating from a primary station to a plurality of secondary stations according to the features of claim 1.

[0010] As a consequence, the hash functions proposed here aim to reduce the likelihood of persistent collisions. In fact, the hash functions are such that the probability that different UEs collide in two subframes is approximately equal to the probability that two UEs collide in the first of these subframes times the probability that two UEs collide in the second of these subframes. Thus, it is unlikely that two UEs collide repeatedly.

[0011] The present invention also relates to a primary station comprising means for communicating with a primary plurality of secondary stations according to the features of claim 7.

[0012] In accordance with still another aspect of the invention, it is proposed a secondary station comprising means for communicating with a primary station according to the features of claim 8.

[0013] These and other aspects of the invention will be apparent from and will be elucidated with reference to the embodiments described hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] The present invention will now be described in more detail, by way of example, with reference to the accom-
In fact, we describe functions $f_s(x)$ with $x \in X$, $s \in \{0,1,...,T-1\}$ into $\{0,1,...,M-1\}$. The variable $x$ corresponds to the UE_ID in the present situation, and $s$ to the subframe number. The functions have the following properties.

1. For each $s \in \{0,1,...,T-1\}$, the function $f_s$ attains each element in $\{0,1,...,M-1\}$ approximately equally often.
2. For all distinct s, t in \{0, 1, ..., T-1\}, the number of elements x in X such that \(f_s(x) = i\) and \(f_t(x) = j\) is approximately the same for all values of i and j.

[0024] We propose to use sets of hash functions of the form

\[f_s(x) = (Ax \mod M_s) \mod M\]

where A is a constant number and \(M_0, M_1, ..., M_{T-1}\) are different numbers. It is advantageous if \(M_0, M_1, ..., M_{T-1}\) are relatively prime to each other and to M.

[0025] As a variant of the first embodiment, the following parameters are selected:

\[T = 10, \text{ UE ID in } X = \{0, 1, ..., 2^{24} - 1\}, M = 47, \text{ and } A = 1.\]

For the multipliers \(M_0, M_1, ..., M_9\), we take ten prime numbers close to \(2^{12}\), as depicted in the following table.

<table>
<thead>
<tr>
<th>s</th>
<th>(M_s)</th>
<th>(s)</th>
<th>(M_s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4057</td>
<td>5</td>
<td>4099</td>
</tr>
<tr>
<td>1</td>
<td>4073</td>
<td>6</td>
<td>5003</td>
</tr>
<tr>
<td>2</td>
<td>4079</td>
<td>7</td>
<td>5009</td>
</tr>
<tr>
<td>3</td>
<td>4091</td>
<td>8</td>
<td>5011</td>
</tr>
<tr>
<td>4</td>
<td>4093</td>
<td>9</td>
<td>5021</td>
</tr>
</tbody>
</table>

[0026] To test the “uniformity” of each of the T=10 hash functions, i.e., Property 1 above, we counted for \(i = 0, ..., M-1\), the number of elements \(x \in X\) for which \(f_s(x) = i\). The quotient of the smallest of these numbers and the largest of these numbers is computed. In case of a uniform distribution, this quotient would equal one; we thus wish that the quotient should be approximately one. For our specific choice of \(M_0, M_1, ..., M_9\), the computed quotients range from 0.9885 to 0.9906.

[0027] To test the independence of the hash functions \(f_s\) and \(f_t\), i.e., Property 2 above, we computed for all pairs \((ij)\) the number elements \(x \in X\) for which \(f_s(x) = i\) and \(f_t(x) = j\).

[0028] Next, we computed the quotient of the smallest of these \(M^2\) numbers and the largest of these \(M^2\) numbers. Ideally, we would like this quotient to be equal to one. For our specific choice of \(M_0, M_1, ..., M_9\), the computed quotients range from 0.9752 to 0.9808.

[0029] We can conclude that in the embodiment, the hash functions are approximately uniform and approximately independent.

[0030] In the envisioned application, the values of T and the range X is fixed while M may vary. For implementation reasons, it is advantageous that \(M_0, M_1, ..., M_{T-1}\) do not depend on M. If we change M to 24, the computed quotients for uniformity range from 0.9941 to 0.9952; the computed quotients for testing independence range from 0.9779 to 0.9889. So also for this case, the proposed hash functions are approximately uniform and approximately independent. If we change M to 120, the computed quotients for uniformity range from 0.9706 to 0.9762; those for testing independence range from 0.9330 to 0.9474.

[0031] The invention may be applicable to mobile telecommunication systems like UMTS LTE and UMTS LTE-Advanced, but also in some variants to any communication system having allocation of resources to be done dynamically or at least semi persistently.

[0032] In the present specification and claims the word "a" or "an" preceding an element does not exclude the presence of a plurality of such elements. Further, the word "comprising" does not exclude the presence of other elements or steps than those listed.

[0033] The inclusion of reference signs in parentheses in the claims is intended to aid understanding and is not intended to be limiting.

[0034] From reading the present disclosure, other modifications will be apparent to persons skilled in the art. Such modifications may involve other features which are already known in the art of radio communication.

Claims

1. A method for communicating between a primary station (100) and a plurality of secondary stations (110), comprising
the steps

(a) each secondary station is configured to search at least one of a plurality of search spaces, each search space comprising at least one resource set, where at least one resource set is used to transmit a message to the considered secondary station,

(b) the search space of a given secondary station is determined on the basis of a hash function \( f_s(x) \) with \( x \in X, s \in \{0,1,\ldots,T-1\} \) into \{0,1,\ldots,M-1\}, where \( x \) corresponds to an identifier of the secondary station, \( s \) to a subframe number, \( X \) to a fixed range value, \( T \) to the number of hash functions, and \( M \) to a constant, wherein the hash function has the following properties:

- for each \( s \in \{0,1,\ldots,T-1\} \), the function \( f_s \) attains each element in \{0,1,\ldots,M-1\} approximately equally often;
- for all distinct \( s,t \in \{0,1,\ldots,T-1\} \) of hash functions \( f_s(x) \) and \( f_t(x) \), the number of elements \( x \) in \( X \) such that \( f_s(x)=i \) and \( f_t(x)=j \) is approximately the same for all values of indexes \( i \) and \( j \);

(c) at each secondary station, searching in the configured at least one search space for a control message from the primary station addressed to the considered secondary station, and receiving the control message.

2. The method of claim 1, wherein for two distinct subframes, \( s \) and \( t \), the outputs of the hash functions are substantially independent from each other.

3. The method of any of the preceding claims, wherein the hash function has the form:

\[
f(x,s)=(h(x)\mod g(s))\mod M,\]

where \( x \) is a parameter of each secondary station, \( s \) is the subframe number, \( h \) is a function dependent on \( x \), \( g \) is a function dependent on \( s \), \( M \) is a constant, and \( \mod \) is the modulo function.

4. The method of claim 3, wherein \( h \) is a constant multiplier.

5. The method of claim 3 or 4, wherein the parameter of the secondary station is an identifier of the secondary station.

6. The method of any of claims 3 to 5, wherein for each value of \( s \), \( g(s) \) is a prime number.

7. A primary station (100) comprising means for communicating with a plurality of secondary station (110), the primary station further comprising allocating means to allocate at least one resource set to a given secondary station into at least one of a plurality of search spaces, each search space comprising at least one resource set, wherein the search space of the given secondary station is determined on the basis of a hash function \( f_s(x) \) with \( x \in X, s \in \{0,1,\ldots,T-1\} \) into \{0,1,\ldots,M-1\}, where \( x \) corresponds to an identifier of the secondary station, \( s \) to a subframe number, \( X \) to a fixed range value, \( T \) to the number of hash functions, and \( M \) to a constant, wherein the hash function has the following properties:

- for each \( s \in \{0,1,\ldots,T-1\} \), the function \( f_s \) attains each element in \{0,1,\ldots,M-1\} approximately equally often;
- for all distinct \( s,t \in \{0,1,\ldots,T-1\} \) of hash functions \( f_s(x) \) and \( f_t(x) \), the number of elements \( x \) in \( X \) such that \( f_s(x)=i \) and \( f_t(x)=j \) is approximately the same for all values of indexes \( i \) and \( j \).

8. A secondary station (110) comprising means for communicating with a primary station (100), the secondary station further comprising control means configured to search at least one of a plurality of search spaces, each search space comprising at least one resource set, where at least one resource set is used to transmit a message to the considered secondary station, wherein the search space of the secondary station is determined on the basis of a hash function \( f_s(x) \) with \( x \in X, s \in \{0,1,\ldots,T-1\} \) into \{0,1,\ldots,M-1\}, where \( x \) corresponds to an identifier of the secondary station, and \( s \) to a subframe number, \( X \) to a fixed range value, \( T \) to the number of hash functions, and \( M \) to a constant, wherein the hash function has the following properties:

- for each \( s \in \{0,1,\ldots,T-1\} \) of hash functions \( f_s(x) \) and \( f_t(x) \), the function \( f_s \) attains each element in \{0,1,\ldots,M-1\} approximately equally often;
- for all distinct \( s,t \in \{0,1,\ldots,T-1\} \), the number of elements \( x \) in \( X \) such that \( f_s(x)=i \) and \( f_t(x)=j \) is approximately the same for all values of indexes \( i \) and \( j \); wherein the control means are configured for searching in the configured at least one search space for a control message from the primary station addressed to the considered secondary station, and receiving the control message.
message.

Patentansprüche

1. Verfahren zur Kommunikation zwischen einer Primärstation (100) und mehreren Sekundärstationen (110), wobei das Verfahren die folgenden Schritte umfasst, wonach:

(a) jede Sekundärstation so konfiguriert ist, dass sie mindestens einen von mehreren Suchräumen sucht, wobei jeder Suchraum mindestens einen Ressourcensatz umfasst, wobei mindestens ein Ressourcensatz zur Übertragung einer Nachricht zu der ins Auge gefassten Sekundärstation verwendet wird,
(b) der Suchraum einer vorgegebenen Sekundärstation auf der Grundlage einer Hash-Funktion $f_s(x)$ mit $x \in X$, $s \in \{0,1,...,T-1\}$ in $\{0,1,...,M-1\}$ ermittelt wird, wobei $x$ einem Identifikator der Sekundärstation, $s$ einer Subframe-Nummer, $X$ einem festen Bereichswert, $T$ der Anzahl von Hash-Funktionen und $M$ einer Konstante entspricht, wobei die Hash-Funktion die folgenden Eigenschaften aufweist:

- für jede $s \in \{0,1,...,T-1\}$ erreicht die Funktion $f_s$ jedes Element in $\{0,1,...,M-1\}$ in etwa gleich häufig;
- für alle verschiedenen $s,t$ in $\{0,1,...,T-1\}$ von Hash-Funktionen $f_s(x)$ und $f_t(x)$ ist die Anzahl von Elementen $x$ in $X$ so dass $f_s(x)=i$ und $f_t(x)=j$ in etwa die gleiche für alle Werte von Indizes $i$ und $j$;

(c) wobei an jeder Sekundärstation in dem konfigurierten, mindestens einen Suchraum nach einer an die ins Auge gefasste Sekundärstation adressierte Control-Message von der Primärstation gesucht und die Control-Message empfangen wird.

2. Verfahren nach Anspruch 1, wobei für zwei verschiedene Subframes, $s$ und $t$, die Ausgaben der Hash-Funktionen im Wesentlichen voneinander unabhängig sind.

3. Verfahren nach einem der vorangegangenen Ansprüche, wobei die Hash-Funktion die folgende Form aufweist:

\[ (x,s) = (h(x) \mod g(s)) \mod M, \]

wobei $x$ einen Parameter jeder Sekundärstation, $s$ die Subframe-Nummer, $h$ eine von $x$ abhängige Funktion, $g$ eine von $s$ abhängige Funktion, $M$ eine Konstante und $\mod$ die Modulo-Funktion darstellen.

4. Verfahren nach Anspruch 3, wobei $h$ einen Konstantenmultiplizierer darstellt.

5. Verfahren nach Anspruch 3 oder 4, wobei der Parameter der Sekundärstation ein Identifikator der Sekundärstation ist.

6. Verfahren nach einem der Ansprüche 3 bis 5, wobei $g(s)$ eine Primzahl für jeden Wert von $s$ darstellt.

7. Primärstation (100) mit Mitteln zum Kommunizieren mit mehreren Sekundärstationen (110), wobei die Primärstation weiterhin umfasst:

Zuordnungsmittel, um einer vorgegebenen Sekundärstation in mindestens einem von mehreren Suchräumen mindestens einen Ressourcensatz zuzuordnen, wobei jeder Suchraum mindestens einen Ressourcensatz umfasst, wobei der Suchraum der vorgegebenen Sekundärstation auf der Grundlage einer Hash-Funktion $f_s(x)$ mit $x \in X$, $s \in \{0,1,...,T-1\}$ in $\{0,1,...,M-1\}$ ermittelt wird, wobei $x$ einem Identifikator der Sekundärstation, $s$ einer Subframe-Nummer, $X$ einem festen Bereichswert, $T$ der Anzahl von Hash-Funktionen und $M$ einer Konstante entspricht, wobei die Hash-Funktion die folgenden Eigenschaften aufweist:

- für jede $s \in \{0,1,...,T-1\}$ erreicht die Funktion $f_s$ jedes Element in $\{0,1,...,M-1\}$ in etwa gleich häufig;
- für alle verschiedenen $s,t$ in $\{0,1,...,T-1\}$ von Hash-Funktionen $f_s(x)$ und $f_t(x)$ ist die Anzahl von Elementen $x$ in $X$ so dass $f_s(x)=i$ und $f_t(x)=j$ in etwa die gleiche für alle Werte von Indizes $i$ und $j$.

8. Sekundärstation (110) mit Mitteln zum Kommunizieren mit einer Primärstation (100), wobei die Sekundärstation weiterhin umfasst:

Steuermittel, die so konfiguriert sind, dass sie mindestens einen von mehreren Suchräumen suchen, wobei jeder Suchraum mindestens einen Ressourcensatz umfasst, wobei mindestens ein Ressourcensatz zur Über-
tragung einer Nachricht zu der ins Auge gefassten Sekundärstation verwendet wird, wobei der Suchraum der Sekundärstation auf der Grundlage einer Hash-Funktion \( f_s(x) \) mit \( x \in X, s \in \{0, 1, \ldots, T - 1\} \) in \( 0, 1, \ldots, M - 1 \) ermittelt wird, wobei \( x \) einem Identifikator der Sekundärstation, \( s \) einer Subframe-Nummer, \( X \) einem festen Bereichswert, \( T \) der Anzahl von Hash-Funktionen und \( M \) einer Konstante entspricht, wobei die Hash-Funktion die folgenden Eigenschaften aufweist:

- für jede \( s \in \{0, 1, \ldots, T - 1\} \) von Hash-Funktionen \( f_s(x) \) und \( f_t(x) \) erreicht die Funktion \( f_s \) jedes Element in \( \{0, 1, \ldots, M - 1\} \) in etwa gleich häufig;
- für alle verschiedenen \( s, t \) in \( \{0, 1, \ldots, T - 1\} \) ist die Anzahl von Elementen \( x \) in \( X \) so dass \( f_s(x) = i \) und \( f_t(x) = j \) in etwa die gleiche für alle Werte von Indizes \( i \) und \( j \);

wobei die Steuermittel so konfiguriert sind, dass sie in dem konfigurierten, mindestens einen Suchraum nach einer an die in Betracht gezogene Sekundärstation adressierte Control-Message von der Primärstation suchen und die Control-Message empfangen.

**Revidcations**

1. Procédé de communication entre une station primaire (100) et une pluralité de stations secondaires (110), comprenant les étapes suivantes dans lesquelles :

   (a) chaque station secondaire est configurée pour rechercher dans au moins l’un d’une pluralité d’espaces de recherche, chaque espace de recherche comprenant au moins un ensemble de ressources, où au moins un ensemble de ressources est utilisé pour transmettre un message à la station secondaire considérée,

   (b) l’espace de recherche d’une station secondaire donnée est déterminé sur la base d’une fonction de hachage \( f_s(x) \) avec \( x \in X, s \in \{0, 1, \ldots, T - 1\} \) en \( \{0, 1, \ldots, M - 1\} \), où \( x \) correspond à un identifiant de la station secondaire, \( s \) à un nombre de secteur de trame, \( X \) à une valeur de plage fixe, \( T \) au nombre de fonctions de hachage, et \( M \) à une constante, où la fonction de hachage a les propriétés suivantes :

   - pour chaque \( s \in \{0, 1, \ldots, T - 1\} \), la fonction \( f_s \) atteint chaque élément dans \( \{0, 1, \ldots, M - 1\} \) approximativement aussi souvent ;

   - pour tout \( s, t \) distinct dans \( \{0, 1, \ldots, T - 1\} \) de fonctions de hachage \( f_s(x) \) et \( f_t(x) \), le nombre d’éléments \( x \) dans \( X \) tel que \( f_s(x) = i \) et \( f_t(x) = j \) est approximativement le même pour toutes les valeurs d’indice de \( i \) et \( j \) ;

   et l’étape consistant à :

   (c) à chaque station secondaire, rechercher dans le au moins un espace de recherche configuré un message de commande provenant de la station primaire adressé à la station secondaire considérée, et recevoir le message de commande.

2. Procédé selon la revendication 1, dans lequel pour deux secteurs de trame distincts, \( s \) et \( t \), les sorties des fonctions de hachage sont sensiblement indépendantes les unes des autres.

3. Procédé selon l’une quelconque des revendications précédentes, dans lequel la fonction de hachage a la forme :

   \( \cdot (x, s) = (h(x)\text{mod } g(s))\text{mod } M \), où \( x \) est un paramètre de chaque station secondaire, \( s \) est le numéro de secteur de trame, \( h \) est une fonction dépendant de \( x \), \( g \) est une fonction dépendant de \( s \), \( M \) est une constante, et mod est la fonction modulo.

4. Procédé selon la revendication 3, dans lequel \( h \) est un multiplicateur constant.

5. Procédé selon la revendication 3 ou 4, dans lequel le paramètre de la station secondaire est un identifiant de la station secondaire.

6. Procédé selon l’une quelconque des revendications 3 à 5, dans lequel pour chaque valeur de \( s \), \( g(s) \) est un nombre premier.

7. Station primaire (100) comprenant un moyen de communication avec une pluralité de stations secondaires (110), la station primaire comprenant en outre :
l’attribution d’un moyen d’attribution d’au moins un ensemble de ressources à une station secondaire donnée dans au moins l’un d’une pluralité d’espaces de recherche, chaque espace de recherche comprenant au moins un ensemble de ressources, dans laquelle l’espace de recherche de la station secondaire donnée est déterminé sur la base d’une fonction de hachage \( f_s(x) \) avec \( x \cdot X, s \in \{0,1,\ldots,T-1\} \) dans \( \{0,1,\ldots,M-1\} \), où \( x \) correspond à un identifiant de la station secondaire, \( s \) à un nombre de secteur de trame, \( X \) à une valeur de plage fixe, \( T \) au nombre de fonctions de hachage, et \( M \) à une constante, où la fonction de hachage a les propriétés suivantes :

- pour chaque \( s \in \{0,1,\ldots,T-1\} \), la fonction \( f_s \) atteint chaque élément dans \( \{0,1,\ldots,M-1\} \) approximativement aussi souvent ;
- pour tout \( s,t \) distinct dans \( \{0,1,\ldots,T-1\} \) de fonctions de hachage \( f_s(x) \) et \( f_t(x) \), le nombre d’éléments \( x \) dans \( X \) tel que \( f_s(x) = i \) et \( f_t(x) = j \) est approximativement le même pour toutes les valeurs d’indice \( i \) et \( j \).

8. Station secondaire (110) comprenant un moyen de communication avec une station primaire (100), la station secondaire comprenant en outre :

un moyen de commande configuré pour rechercher dans au moins l’un d’une pluralité d’espaces de recherche, chaque espace de recherche comprenant au moins un ensemble de ressources, où au moins un ensemble de ressources est utilisé pour transmettre un message à la station secondaire considérée, où l’espace de recherche de la station secondaire est déterminé sur la base d’une fonction de hachage \( f_s(x) \) avec \( x \cdot X, s \in \{0,1,\ldots,T-1\} \) dans \( \{0,1,\ldots,M-1\} \), où \( x \) correspond à un identifiant de la station secondaire, et \( s \) à un numéro de secteur de trame, \( X \) à une valeur de plage fixe, \( T \) au nombre de fonctions de hachage, et \( M \) à une constante, où la fonction de hachage a les propriétés suivantes :

- pour chaque \( s \in \{0,1,\ldots,T-1\} \) de fonctions de hachage \( f_s(x) \) et \( f_t(x) \), la fonction \( f_s \) atteint chaque élément dans \( \{0,1,\ldots,M-1\} \) approximativement aussi souvent ;
- pour tout \( s,t \) distinct dans \( \{0,1,\ldots,T-1\} \), le nombre d’éléments \( x \) dans \( X \) tel que \( f_s(x) = i \) et \( f_t(x) = j \) est approximativement le même pour toutes les valeurs d’indice \( i \) et \( j \) ;

où les moyens de commande sont configurés pour rechercher dans le au moins un espace de recherche un message de commande provenant de la station primaire adressé à la station secondaire prise en considération, et recevoir le message de commande.