# TIME SYNCHRONIZED CHANNEL HOPPING SEQUENCE GENERATION AND USE FOR WIRELESS RF COMMUNICATIONS

## FIELD

The present disclosure relates to methods for use in Time Synchronized Channel Hopping (TSCH) wireless RF communications, and a wireless RF communication device.

## BACKGROUND

Mesh communication networks may be used for resource metering. For example, network endpoints, such as metering devices, can communicate wirelessly with other nodes or devices included in the mesh communication network. Mesh communication networks may use TSCH techniques for enhanced communication reliability between the nodes or devices of the mesh communication network. Specifically, RF transceivers at different nodes or devices of the mesh communication network may communicate wirelessly according to a TSCH sequence which comprises M time slots and M corresponding RF channel frequencies, wherein each RF channel frequency is selected from a set of N RF channel frequencies, and wherein each wireless RF transceiver is configured to transmit or receive a corresponding wireless RF signal in each time slot of the corresponding TSCH sequence at the corresponding RF channel frequency.

Each node or device of the mesh communication network may include two or more neighboring wireless RF transceivers to enable the simultaneous transmission of wireless RF signals from the neighboring wireless RF transceivers to two or more other nodes or devices of the mesh communication network and/or to enable the simultaneous reception of wireless RF signals at the neighboring wireless RF transceivers from two or more other nodes or devices of the mesh communication network. However, when using such TSCH techniques, simultaneous transmission and/or reception of wireless RF signals using two or more neighboring wireless RF transceivers can lead to multiple wireless RF transceivers operating on the same RF channel frequency at the same time thereby resulting in self-interference and subsequent performance degradation.

## SUMMARY

According to an aspect of the present disclosure there is provided a method for use in determining a set of S compatible time-synchronized channel hopping sequences

for transmitting and/or receiving wireless RF signals at S neighboring wireless RF transceivers, the method comprising:

generating at least S hopping sequences, each hopping sequence comprising M time slots, each time slot having a corresponding RF channel frequency, and the RF channel frequency in each time slot being selected from a set of N RF channel frequencies; and

determining whether there exists one or more sets of S compatible hopping sequences from among the at least S generated hopping sequences, wherein none of the hopping sequences of each set of S compatible hopping sequences have the same RF channel frequency in the same time slot and none of the hopping sequences of each set of S compatible hopping sequences have the same RF channel frequency in adjacent time slots,

wherein S, M and N are integers, and S is greater than or equal to two.

Such a method may be used to determine a set of S compatible time-synchronized channel hopping sequences for transmitting and/or receiving wireless RF signals at S neighboring wireless RF transceivers which limits or minimises self-interference between the neighboring TSCH wireless RF transceivers even when the time synchronization between the neighboring TSCH wireless RF transceivers and other TSCH wireless transceivers deteriorates or fails.

Optionally, the step of generating at least S hopping sequences and the step of determining whether there exists one or more sets of S compatible hopping sequences from among the at least S generated hopping sequences are performed sequentially.

Optionally, the step of generating at least S hopping sequences and the step of determining whether there exists one or more sets of S compatible hopping sequences from among the at least S generated hopping sequences at least partially overlap.

Optionally, each of the at least S generated hopping sequences are different.

Optionally, each time slot of each generated hopping sequence has a different RF channel frequency to the RF channel frequency of each of the other times slots of the same generated hopping sequence.

Optionally, generating the at least S hopping sequences comprises using a Linear Feedback Shift Register with at least S different hopping sequence ID numbers as seeds.

Optionally, the Linear Feedback Shift Register is configured so that for each different hopping sequence ID number, the Linear Feedback Shift Register generates a different hopping sequence.

Optionally, the Linear Feedback Shift Register is configured so that each time slot of each generated hopping sequence has a different RF channel frequency to the RF channel frequency of each of the other times slots of the same generated hopping sequence.

Optionally, generating the at least S hopping sequences comprises generating P hopping sequences, wherein P is an integer greater than or equal to S.

Optionally, determining whether there exists one or more sets of S compatible hopping sequences from among the at least S generated hopping sequences comprises determining whether there exists one or more sets of S compatible hopping sequences from among the P generated hopping sequences.

Optionally, the method comprises generating all of the P hopping sequences and then determining whether there exists one or more sets of S compatible hopping sequences from among the P generated hopping sequences.

Optionally,

i) wherein generating the at least S hopping sequences comprises generating P different hopping sequences, each generated hopping sequence comprising M time slots, each time slot having a corresponding RF channel frequency, and the RF channel frequency in each time slot being selected from the set of N RF channel frequencies, wherein P is an integer greater than or equal to S; and

ii) wherein determining whether there exists one or more sets of S compatible hopping sequences from among the at least S generated hopping sequences comprises:

iii) selecting a first compatible hopping sequence $CHS_1$ from among the P different generated hopping sequences;

iv) selecting a hopping sequence $HS_x$ from among the P different generated hopping sequences;

v) identifying the selected hopping sequence $HS_x$ as a $y^{th}$ compatible hopping sequence $CHS_y$ if:

the selected hopping sequence $HS_x$ and any of the previously generated compatible hopping sequences $CHS_1$ … $CHS_{y-1}$ do not have the same RF channel frequency in the same time slot; and

the hopping sequence $HS_x$ and any of the previously generated compatible hopping sequences $CHS_1$ … $CHS_{y-1}$ do not have the same RF channel frequency in adjacent time slots; and

vi) repeating steps iv) and v) until a set of S compatible hopping sequences $CHS_1$ ... $CHS_S$ is identified or until all of the P different generated hopping sequences have been selected.

Optionally, determining whether the hopping sequence $HS_x$ and any of the previously generated compatible hopping sequences $CHS_1$ ... $CHS_{y-1}$ do not have the same RF channel frequency in adjacent time slots at step v) comprises:

determining a first time-shifted hopping sequence $HS_{xR}$ wherein the RF channel frequency in each time slot of the first time-shifted hopping sequence $HS_{xR}$ except the first time slot of the first time-shifted hopping sequence $HS_{xR}$ corresponds to the RF channel frequency in the preceding time slot of the hopping sequence $HS_x$ and wherein the RF channel frequency in the first time slot of the first time-shifted hopping sequence $HS_{xR}$ comprises the RF channel frequency in the last time slot of the hopping sequence $HS_x$;

determining whether the RF channel frequency in each time slot of the first time-shifted hopping sequence $HS_{xR}$ is the same as the RF channel frequency in the corresponding time slot of each of the previously generated compatible hopping sequences $CHS_1$ ... $CHS_{y-1}$;

determining a second time-shifted hopping sequence $HS_{xL}$ wherein the RF channel frequency in each time slot of the second time-shifted hopping sequence $HS_{xL}$ except the last time slot of the second time-shifted hopping sequence $HS_{xL}$ corresponds to the RF channel frequency in the next successive time slot of the hopping sequence $HS_x$ and wherein the RF channel frequency in the last time slot of the second time-shifted hopping sequence $HS_{xL}$ comprises the RF channel frequency in the first time slot of the hopping sequence $HS_x$; and

determining whether the RF channel frequency in each time slot of the second time-shifted hopping sequence $HS_{xL}$ is the same as the RF channel frequency in the corresponding time slot of each of the previously generated compatible hopping sequences $CHS_1$ ... $CHS_{y-1}$.

Optionally, the method comprises, responsive to determining that all of the P different generated hopping sequences have been selected at step vi), increasing at least one of P, M and N, and repeating steps i) – vi) until a set of S compatible hopping sequences is identified or until it is not possible to generate a set of P different hopping sequences at step i).

Optionally, generating the at least S hopping sequences and determining whether there exists one or more sets of S compatible hopping sequences from among the at least S generated hopping sequences comprises:

i) generating a first compatible hopping sequence $CHS_1$ comprising M time slots, each time slot having a corresponding RF channel frequency, and the RF channel frequency in each time slot being selected from the set of N RF channel frequencies;

ii) generating a hopping sequence $HS_x$ comprising M time slots, each time slot having a corresponding RF channel frequency, and the RF channel frequency in each time slot being selected from the set of N RF channel frequencies, wherein the generated hopping sequence $HS_x$ is different to any previously generated hopping sequence;

iii) identifying the generated hopping sequence $HS_x$ as a $y^{th}$ compatible hopping sequence $CHS_y$ if:

the hopping sequence $HS_x$ and any of the previously generated compatible hopping sequences $CHS_1$ ... $CHS_{y-1}$ do not have the same RF channel frequency in the same time slot, and

the hopping sequence $HS_x$ and any of the previously generated compatible hopping sequences $CHS_1$ ... $CHS_{y-1}$ do not have the same RF channel frequency in adjacent time slots, and

iv) repeating steps ii) and iii) until a set of S compatible hopping sequences $CHS_1$ ... $CHS_S$ is identified or until P different hopping sequences have been generated, wherein P is an integer greater than or equal to S.

Optionally, determining whether the hopping sequence $HS_x$ and any of the previously generated compatible hopping sequences $CHS_1$ ... $CHS_{y-1}$ do not have the same RF channel frequency in adjacent time slots at step iv)comprises:

determining a first time-shifted hopping sequence $HS_{xR}$ wherein the RF channel frequency in each time slot of the first time-shifted hopping sequence $HS_{xR}$ except the first time slot of the first time-shifted hopping sequence $HS_{xR}$ corresponds to the RF channel frequency in the preceding time slot of the hopping sequence $HS_x$ and wherein the RF channel frequency in the first time slot of the first time-shifted hopping sequence $HS_{xR}$ comprises the RF channel frequency in the last time slot of the hopping sequence $HS_x$;

determining whether the RF channel frequency in each time slot of the first time-shifted hopping sequence $HS_{xR}$ is the same as the RF channel frequency in the

corresponding time slot of each of the previously generated compatible hopping sequences $CHS_1$ ... $CHS_{y-1}$;

determining a second time-shifted hopping sequence $HS_{xL}$ wherein the RF channel frequency in each time slot of the second time-shifted hopping sequence $HS_{xL}$ except the last time slot of the second time-shifted hopping sequence $HS_{xL}$ corresponds to the RF channel frequency in the next successive time slot of the hopping sequence $HS_x$ and wherein the RF channel frequency in the last time slot of the second time-shifted hopping sequence $HS_{xL}$ comprises the RF channel frequency in the first time slot of the hopping sequence $HS_x$; and

determining whether the RF channel frequency in each time slot of the second time-shifted hopping sequence $HS_{xL}$ is the same as the RF channel frequency in the corresponding time slot of each of the previously generated compatible hopping sequences $CHS_1$ ... $CHS_{y-1}$.

Optionally, the method comprises, responsive to determining that P different hopping sequences have been generated at step iv), increasing at least one of P, M and N, and repeating steps i) – iv)until a set of S compatible hopping sequences is identified or until it is not possible to generate a hopping sequence $HS_x$ at step ii) which is different to any previously generated hopping sequences $HS_x$.

Optionally, S is equal to three or more.

Optionally, M is less than N.

Optionally, M is equal to N.

Optionally, M is 64.

Optionally, N is 64 or 128.

Optionally, none of the hopping sequences of each set of S compatible hopping sequences have the same RF channel frequency in non-adjacent time slots, each pair of non-adjacent time slots being offset from one another in time by a predetermined number of time slots which is greater than or equal to two, for example wherein the predetermined number of time slots is two or three.

According to an aspect of the present disclosure there is provided a method of wireless RF communication comprising:

the method for use in determining a set of S compatible time-synchronized channel hopping sequences for transmitting and/or receiving wireless RF signals at S neighboring wireless RF transceivers as described above,

wherein the method of wireless RF communication further comprises:

in response to determining that there exists one or more sets of S compatible hopping sequences from among the at least S generated hopping sequences, selecting one of the one or more sets of S compatible hopping sequences for transmitting and/or receiving wireless RF signals at the S neighboring wireless RF transceivers; and

using the hopping sequences of the selected set of S compatible hopping sequences at respective wireless RF transceivers of the S neighboring wireless RF transceivers to transmit and/or receive respective wireless RF signals at the S neighboring wireless RF transceivers.

Optionally, using the hopping sequences of the selected set of S compatible hopping sequences at respective wireless RF transceivers of the S neighboring wireless RF transceivers to transmit and/or receive respective wireless RF signals at the S neighboring wireless RF transceivers comprises repeatedly using the hopping sequences of the selected set of S compatible hopping sequences at respective wireless RF transceivers of the S neighboring wireless RF transceivers to transmit and/or receive respective wireless RF signals at the S neighboring wireless RF transceivers so that the RF channel frequency used by each of the S neighboring wireless RF transceivers is cycled repeatedly through all of the RF channel frequencies of the corresponding hopping sequence from the first time slot to the $M^{th}$ time slot during transmission and/or reception of the corresponding wireless RF signal.

According to an aspect of the present disclosure there is provided a wireless RF communication device such as a wireless RF network gateway device, wherein the wireless RF communication device comprises S neighboring wireless RF transceivers, wherein the S wireless RF transceivers are configured to use respective hopping sequences of a set of S compatible hopping sequences selected from the one or more sets of S compatible hopping sequences determined using the method as described above to transmit and/or receive respective wireless RF signals.

According to an aspect of the present disclosure there is provided a method for identifying whether the time synchronized channel hopping sequences of a set of S time synchronized channel hopping sequences are compatible with one another for the transmission and/or reception of S wireless RF signals at S neighboring wireless RF transceivers, wherein each hopping sequence comprises M time slots, each time slot having a corresponding RF channel frequency, and the RF channel frequency in each time slot being selected from a set of N RF channel frequencies, and wherein the method comprises:

identifying that the set of S hopping sequences are compatible with one another if none of the hopping sequences of the set of S hopping sequences have the same RF channel frequency in the same time slot and none of the hopping sequences of the set of S hopping sequences have the same RF channel frequency in adjacent time slots,

wherein S, M and N are integers, and S is greater than or equal to two.

Optionally, the method for identifying whether the time synchronized channel hopping sequences of a set of S time synchronized channel hopping sequences are compatible with one another for the transmission and/or reception of S wireless RF signals at S neighboring wireless RF transceivers comprises:

using the method described above to identify that a set of S time synchronized channel hopping sequences are compatible with one another for the transmission and/or reception of S wireless RF signals at S neighboring wireless RF transceivers; and

using the hopping sequences of the set of S hopping sequences at respective wireless RF transceivers of the S neighboring wireless RF transceivers to transmit and/or receive respective wireless RF signals at the S neighboring wireless RF transceivers.

It should be understood that any one or more of the features of any one of the foregoing aspects of the present disclosure may be combined with any one or more of the features of any of the other foregoing aspects of the present disclosure.

## BRIEF DESCRIPTION OF THE DRAWINGS

Apparatus and methods will now be described by way of non-limiting example only with reference to the accompanying drawings of which:

FIG. 1 is a schematic of a wireless RF communication device;

FIG. 2 shows three known hopping sequences for use by three neighboring wireless RF transceivers of the wireless RF communication device of FIG. 1;

FIG. 3 illustrates a method for determining a set of three "compatible" hopping sequences for three neighboring wireless RF transceivers of the wireless RF communication device of FIG. 1;

FIG. 4 illustrates ten different hopping sequence ID numbers and the hopping sequence ID numbers of one or more sets of three compatible hopping sequences corresponding to each hopping sequence ID number, wherein the one or more sets of three compatible

hopping sequences are generated by applying the method of FIG. 3 for each different initial hopping sequence ID number in a range of different initial hopping sequence ID numbers;

FIG. 5 illustrates a method for determining a set of S "compatible" hopping sequences for S neighboring wireless RF transceivers;

FIG. 6 illustrates a method for identifying whether a set of S hopping sequences are compatible with one another for the transmission and/or reception of S wireless RF signals at S neighboring wireless RF transceivers; and

FIG. 7 shows the results of the method of FIG. 6 when applied to the three known hopping sequences of FIG. 2.

**DETAILED DESCRIPTION OF THE DRAWINGS**

Referring initially to FIG. 1 there is shown a wireless RF communication device generally designated 2 in the form of a wireless RF network gateway device that includes a housing 3 and three neighboring Time Synchronized Channel Hopping (TSCH) wireless RF transceivers 4 such as three neighboring TSCH collector radios (CR) located within the housing 3. Each CR 4 is the co-ordinator or root of a corresponding IEEE 802.15.4e-based Personal Area Network (PAN) PAN 1, PAN 2, and PAN3. In the ideal case, each of the PANs, PAN 1, PAN 2, and PAN3, would be synchronized to a single time source and would have coincident time slot boundaries for each of the PANs, PAN 1, PAN 2, and PAN3. Each CR 4 is configured to transmit and/or receive data according to a hopping sequence comprising M time slots, each time slot having a different RF channel frequency, wherein each RF channel frequency is selected from a set of N RF channel frequencies. However, one or more of the CRs 4 may transmit or receive a wireless RF signal at the same time as one or more of the other CRs 4 transmits or receives a wireless RF signal on the same RF channel frequency leading to self-interference.

FIG. 2 shows known first, second and third hopping sequences generated for three different hopSeqId integer values "1" to "3" respectively, wherein each hopping sequence comprises 64 time slots, wherein each time slot has a corresponding different RF channel frequency, and wherein each RF channel frequency is selected from a set of 64 different RF channel frequencies. One of ordinary skill in the art will understand

that the RF channel frequencies appearing in FIG. 2 are RF channel frequency numbers or identifiers rather than absolute frequency values expressed in physical units such as MHz or GHz, wherein each frequency number or identifier has a known one-to-one correspondence with a corresponding absolute frequency value expressed in physical units such as MHz or GHz. Two or more of the first, second and third hopping sequences have the potential to interfere with one another during a time slot if any two or more of the first, second and third hopping sequences have the same RF channel frequency in the same time slot.

The inventors have discovered that RF channel frequency alignment in adjacent time slots may also be problematic if the time synchronization between the wireless RF communication device 2 and one or more further wireless RF communication devices of the PANs, PAN 1, PAN 2, and PAN3, deteriorates or fails because the transceivers of the wireless RF communication device 2 and the transceivers of the one or more further wireless RF communication devices of the PANs, PAN 1, PAN 2, and PAN3, may not hop to the new channel frequencies at the correct times resulting in failure of the communication link between the transceivers concerned. Thus, the inventors have discovered that two or more of the first, second and third hopping sequences also have the potential to interfere with one another during adjacent time slots as a result of having the same RF channel frequency in adjacent time slots. Specifically:

the first and second hopping sequences have channel frequency alignment at time slot 23, channel 115;

the first and second hopping sequences have channel frequency alignment at adjacent time slots 8/9, channel 15, at adjacent time slots 18/19, channel 13, and at adjacent time slots 58/59, channel 101;

the second and third hopping sequences have no channel frequency alignment;

the second and third hopping sequences have channel frequency alignment at adjacent time slots 12/13, channel 51;

the first and third hopping sequences have channel frequency alignment at time slot 15, channel 69, and at time slot 40, channel 113; and

the first and third hopping sequences have channel frequency alignment at adjacent time slots 21/22, channel 5, at adjacent time slots 23/24, channel 63, at adjacent time slots 32/33, channel 49, and at adjacent time slots 58/59, channel 1.

FIG. 3 illustrates a method for determining a set of three compatible hopping sequences for the three neighboring wireless RF transceivers 4 which limits or minimises self-interference between the neighboring TSCH wireless RF transceivers 4 of the wireless RF communication device 2 even when the time synchronization between the neighboring TSCH wireless RF transceivers 4 and the TSCH wireless transceivers of one or more further wireless RF communication devices of the PANs, PAN 1, PAN 2, and PAN3, deteriorates or fails.

As will be described in more detail below, the method comprises generating a first hopping sequence $HS_{seed}$, wherein the first hopping sequence $HS_{seed}$ comprises M time slots, wherein different time slots have corresponding different RF channel frequencies, wherein each RF channel frequency is selected from a set of N RF channel frequencies, and wherein M and N are integers with M is less than or equal to N. The method further comprises determining a second hopping sequence $HS_{second}$ and a third hopping sequence $HS_{third}$, wherein each of the second and third hopping sequences $HS_{second}$ and $HS_{third}$ comprise M time slots, wherein different time slots of the same hopping sequence have corresponding different RF channel frequencies, wherein each RF channel frequency is selected from the set of N RF channel frequencies, and wherein the second and third hopping sequences $HS_{second}$ and $HS_{third}$ are determined so that the first, second and third hopping sequences $HS_{seed}$, $HS_{second}$, $HS_{third}$ together form a set of three compatible hopping sequences in which none of the hopping sequences of the set of three compatible hopping sequences have the same RF channel frequency in the same time slot and none of the hopping sequences of the set of three compatible hopping sequences have the same RF channel frequency in adjacent time slots.

Determining the second hopping sequence $HS_{second}$ comprises generating a candidate hopping sequence $HS_x$, wherein the candidate hopping sequence $HS_x$ comprises M time slots, different time slots of the candidate hopping sequence $HS_x$ have corresponding different RF channel frequencies, and each RF channel frequency of the candidate hopping sequence $HS_x$ is selected from the set of N RF channel frequencies. Determining the second hopping sequence $HS_{second}$ further comprises selecting the candidate hopping sequence $HS_x$ as the second hopping sequence $HS_{second}$ if:

the RF channel frequencies in the time slots of the candidate hopping sequence $HS_x$ are different to the RF channel frequencies in the corresponding time slots of the first hopping sequence $HS_{seed}$; and

the RF channel frequencies in the time slots of the candidate hopping sequence $HS_x$ are different to the RF channel frequencies in the adjacent time slots of the first hopping sequence $HS_{seed}$.

Determining the third hopping sequence $HS_{third}$ comprises generating a candidate hopping sequence $HS_x$, wherein the candidate hopping sequence $HS_x$ comprises M time slots, different time slots of the candidate hopping sequence $HS_x$ have corresponding different RF channel frequencies, and each RF channel frequency of the candidate hopping sequence $HS_x$ is selected from the set of N RF channel frequencies. Determining the third hopping sequence $HS_{third}$ further comprises selecting the candidate hopping sequence $HS_x$ as the third hopping sequence $HS_{third}$ if:

the RF channel frequencies in the time slots of the candidate hopping sequence $HS_x$ are different to the RF channel frequencies in the corresponding time slot of the first hopping sequence $HS_{seed}$;

the RF channel frequencies in the time slots of the candidate hopping sequence $HS_x$ are different to the RF channel frequencies in the corresponding time slot of the second hopping sequence $HS_{second}$;

the RF channel frequencies in the time slots of the candidate hopping sequence $HS_x$ are different to the RF channel frequencies in the adjacent time slots of the first hopping sequence $HS_{seed}$; and

the RF channel frequencies in the time slots of the candidate hopping sequence $HS_x$ are different to the RF channel frequencies in the adjacent time slots of the second hopping sequence $HS_{second}$.

With reference to FIG. 3, the method begins at step 10 with the generation of the first hopping sequence $HS_{seed}$. Specifically, the method comprises generating 10 the first hopping sequence $HS_{seed}$ by randomly selecting a first hopping sequence ID number from a range of integer values from 0 to 255 and using a Linear Feedback Shift Register (LFSR) with the first hopping sequence ID number as a seed to generate the first hopping sequence $HS_{seed}$ with M different RF channel frequencies in M time slots, wherein each channel frequency is selected from the set of N RF channel frequencies. In this regard, it should be understood that the LFSR is configured so that for each different hopping sequence ID number (hopSeqId) as a seed, the LFSR generates a different hopping sequence. The LFSR may for example be implemented based on the IEEE 15.4

Standard, for example as specified in the IEEE 15.4 Standard or for compliance with the IEEE 15.4 Standard. One of ordinary skill in the art will understand how to implement such a LFSR.

At step 12, the method comprises selecting a first value of a hopping sequence ID number x and using the LFSR with x as a seed to generate a candidate hopping sequence $HS_x$. Specifically, the method comprises setting the hopping sequence ID number x to a value of "0" and using the LFSR with x as a seed to generate the candidate hopping sequence $HS_0$ with M different RF channel frequencies in the M time slots, wherein each channel frequency is selected from the set of N RF channel frequencies.

At step 14, the method comprises checking whether the candidate hopping sequence $HS_x$ and the first hopping sequence $HS_{seed}$ have the same RF channel frequency in the same time slot. If so, the method comprises incrementing x by "1" and using the LFSR with the new integer value of x as a seed to generate a new candidate hopping sequence $HS_x$ at step 16 before returning to step 14.

If the candidate hopping sequence $HS_x$ and the first hopping sequence $HS_{seed}$ do not have the same RF channel frequency in the same time slot, the method comprises time-shifting the candidate hopping sequence $HS_x$ one time slot to the right to generate a right-shifted candidate hopping sequence $HS_{xR}$ at step 18. At step 20, the method comprises checking whether the right-shifted candidate hopping sequence $HS_{xR}$ and the first hopping sequence $HS_{seed}$ have the same RF channel frequency in the same time slot. If so, the method comprises incrementing x by "1" and using the LFSR with the new integer value of x as a seed to generate a new candidate hopping sequence $HS_x$ at step 16 before returning to step 14.

If the right-shifted candidate hopping sequence $HS_{xR}$ and the first hopping sequence $HS_{seed}$ do not have the same RF channel frequency in the same time slot, the method comprises time-shifting the candidate hopping sequence $HS_x$ one time slot to the left to generate a left-shifted candidate hopping sequence $HS_{xL}$ at step 22. At step 24, the method comprises checking whether the left-shifted candidate hopping sequence $HS_{xL}$ and the first hopping sequence $HS_{seed}$ have the same RF channel frequency in the same time slot. If so, the method comprises incrementing x by "1" and using the LFSR with the new integer value of x as a seed to generate a new candidate hopping sequence $HS_x$ at step 16 before returning to step 14.

If the left-shifted candidate hopping sequence $HS_{xL}$ and the first hopping sequence $HS_{seed}$ do not have the same RF channel frequency in the same time slot, the

method comprises selecting the candidate hopping sequence $HS_x$ as the second hopping sequence $HS_{second}$ at step 26.

The method comprises incrementing x by "1" and using the LFSR with the new integer value of x as a seed to generate a new candidate hopping sequence $HS_x$ at step 30.

At step 32, the method comprises checking whether the candidate hopping sequence $HS_x$ and the first hopping sequence $HS_{seed}$ have the same RF channel frequency in the same time slot or whether the candidate hopping sequence $HS_x$ and the second hopping sequence $HS_{second}$ have the same RF channel frequency in the same time slot. If so, the method comprises incrementing x by "1" and using the LFSR with the new integer value of x as a seed to generate a new candidate hopping sequence $HS_x$ at step 30 before returning to step 32.

If the candidate hopping sequence $HS_x$ and the first hopping sequence $HS_{seed}$ do not have the same RF channel frequency in the same time slot and the candidate hopping sequence $HS_x$ and the second hopping sequence $HS_{second}$ do not have the same RF channel frequency in the same time slot, the method comprises time-shifting the candidate hopping sequence $HS_x$ one time slot to the right to generate a right-shifted candidate hopping sequence $HS_{xR}$ at step 34. At step 36, the method comprises checking whether the right-shifted candidate hopping sequence $HS_{xR}$ and the first hopping sequence $HS_{seed}$ have the same RF channel frequency in the same time slot or whether the right-shifted candidate hopping sequence $HS_{xR}$ and the second hopping sequence $HS_{second}$ have the same RF channel frequency in the same time slot. If so, the method comprises incrementing x by "1" and using the LFSR with the new integer value of x as a seed to generate a new candidate hopping sequence $HS_x$ at step 30 before returning to step 32.

If the right-shifted candidate hopping sequence $HS_{xR}$ and the first hopping sequence $HS_{seed}$ do not have the same RF channel frequency in the same time slot and the right-shifted candidate hopping sequence $HS_{xR}$ and the second hopping sequence $HS_{second}$ do not have the same RF channel frequency in the same time slot, the method comprises time-shifting the candidate hopping sequence $HS_x$ one time slot to the left to generate a left-shifted candidate hopping sequence $HS_{xL}$ at step 38. At step 40, the method comprises checking whether the left-shifted candidate hopping sequence $HS_{xL}$ and the first hopping sequence $HS_{seed}$ have the same RF channel frequency in the same time slot or whether the left-shifted candidate hopping sequence $HS_{xL}$ and the second hopping sequence $HS_{second}$ have the same RF channel frequency in the same time slot.

If so, the method comprises incrementing x by "1" and using the LFSR with the new integer value of x as a seed to generate a new candidate hopping sequence $HS_x$ at step 30 before returning to step 32.

If the left-shifted candidate hopping sequence $HS_{xL}$ and the first hopping sequence $HS_{seed}$ do not have the same RF channel frequency in the same time slot and the left-shifted candidate hopping sequence $HS_{xL}$ and the second hopping sequence $HS_{second}$ do not have the same RF channel frequency in the same time slot, the method comprises selecting the candidate hopping sequence $HS_x$ as the third hopping sequence $HS_{third}$ at step 42.

The first, second and third hopping sequences $HS_{seed}$, $HS_{second}$ and $HS_{third}$ are then output at step 44 of the method. As will be appreciated by one of skill in the art, the method described with reference to FIG. 3 results in the determination of a set of first, second and third compatible hopping sequences $HS_{seed}$, $HS_{second}$ and $HS_{third}$, wherein none of the first, second and third compatible hopping sequences $HS_{seed}$, $HS_{second}$ and $HS_{third}$ have the same RF channel frequency in the same time slot and none of the first, second and third compatible hopping sequences $HS_{seed}$, $HS_{second}$ and $HS_{third}$ have the same RF channel frequency in adjacent time slots. As such, the first, second and third compatible hopping sequences $HS_{seed}$, $HS_{second}$ and $HS_{third}$ are suitable for limiting or minimising self-interference between wireless RF signals transmitted from, or received at, the three neighboring wireless RF transceivers 4 of the wireless RF communication device 2, even when the time synchronization between the neighboring TSCH wireless RF transceivers 4 and the TSCH wireless transceivers of one or more further wireless RF communication devices of the PANs, PAN 1, PAN 2, and PAN3, deteriorates or fails. One of skill in the art will also understand that the first, second and third compatible hopping sequences $HS_{seed}$, $HS_{second}$ or $HS_{third}$ are used repeatedly at respective wireless RF transceivers of the three neighboring wireless RF transceivers to transmit and/or receive wireless RF signals at each of the three neighboring wireless RF transceivers so that the RF channel frequency used by each of the three neighboring wireless RF transceivers is cycled repeatedly through all of the RF channel frequencies of the corresponding compatible hopping sequence $HS_{seed}$, $HS_{second}$ or $HS_{third}$ from the first time slot to the $M^{th}$ time slot during transmission and/or reception of the wireless RF signals.

One of skill in the art will understand that in the method of FIG. 3 for determining a set of three compatible hopping sequences for three neighboring TSCH wireless RF transceivers, each candidate hopping sequence $HS_x$ is generated "on-the-fly" when x is incremented until a set of three compatible hopping sequences is found. In a variant of

the method of FIG. 3, the method comprises initially generating P candidate hopping sequences $HS_x$ and then determining whether there exists one or more sets of three compatible hopping sequences from among the P candidate hopping sequences $HS_x$, wherein none of the hopping sequences of each set of three compatible hopping sequences have the same RF channel frequency in the same time slot and none of the hopping sequences of each set of three compatible hopping sequences have the same RF channel frequency in adjacent time slots, wherein P is an integer greater than or equal to three. P may, for example, be "255". In such a variant of the method of FIG. 3, one of the P candidate hopping sequences $HS_x$ is chosen as the first compatible hopping sequence $HS_{seed}$ at step 10 and some of the other P candidate hopping sequences $HS_x$ are compared one at a time with the first compatible hopping sequence $HS_{seed}$ at steps 14, 20 and 24 until a second compatible hopping sequence $HS_{second}$ is determined at step 26. Each of the remaining P candidate hopping sequences $HS_x$ are then compared one at a time with the first and second compatible hopping sequences $HS_{seed}$ and $HS_{second}$ at steps 32, 36 and 40 until a third compatible hopping sequence $HS_{third}$ is determined at step 42.

It should also be understood that the method of FIG. 3, or the variant of the method of FIG. 3, may be repeated for each different initial hopping sequence ID number in a range of initial hopping sequence ID numbers to generate one or more sets of three compatible hopping sequences. All different sets of three compatible hopping sequences which include a given hopping sequence may then be identified from among the generated one or more sets of three compatible hopping sequences. For example, FIG. 4 shows ten different hopSeqId values and the hopping sequence ID numbers of one or more sets of three compatible hopping sequences corresponding to each hopSeqId value, wherein each of the one or more sets of three compatible hopping sequences are generated by applying the method of FIG. 3 for each different initial hopping sequence ID number in a range from "0" to "255" until all sets of three compatible hopping sequences are found for each hopSeqId value for the case where the number of time slots M is "64" and the number of RF channel frequencies N is "128". For example, applying the method of FIG. 3 for each different initial hopping sequence ID number in the range "0" to "255" and then identifying all different sets of three compatible hopping sequences which include the hopping sequence corresponding to the hopSeqId value "19" results in the output of only one set of three compatible hopping sequences identified by one set of three corresponding hopping sequence ID numbers (19, 69, 121), wherein none of the compatible hopping sequences have the same RF channel

frequency in the same time slot and none of the compatible hopping sequences have the same RF channel frequency in adjacent time slots. Similarly, applying the method of FIG. 3 for each different initial hopping sequence ID number in the range "0" to "255" and then identifying all different sets of three compatible hopping sequences which include the hopping sequence corresponding to the hopSeqId value "29" results in the output of two different sets of three compatible hopping sequences identified by two different sets of three corresponding hopping sequence ID numbers (29, 203, 228) and (29, 203, 205), wherein none of the compatible hopping sequences of each different set of three compatible hopping sequences have the same RF channel frequency in the same time slot and none of the compatible hopping sequences of each different set of three compatible hopping sequences have the same RF channel frequency in adjacent time slots.

One of ordinary skill in the art will understand that any one of the sets of three different compatible hopping sequences is suitable for limiting or minimising self-interference between wireless RF signals transmitted from, or received at, the three neighboring wireless RF transceivers 4 of the wireless RF communication device 2, even when the time synchronization between the neighboring TSCH wireless RF transceivers 4 and the TSCH wireless transceivers of one or more further wireless RF communication devices of the PANs, PAN 1, PAN 2, and PAN3, deteriorates or fails. One of ordinary skill in the art will also understand that the larger the range of hopSeqId values, the greater the number of possible sets of three different compatible hopping sequences.

It should be understood that the method of FIG. 3 may be used to determine a set of three compatible hopping sequences for the specific case where there are three neighboring wireless RF transceivers 4. FIG. 5 illustrates a method for determining a set of compatible hopping sequences for the more general case of S neighboring TSCH wireless RF transceivers which limits or minimises self-interference between the neighboring TSCH wireless RF transceivers even when the time synchronization between the neighboring TSCH wireless RF transceivers deteriorates or fails.

The method of FIG. 5 begins at step 110 with generating a first compatible hopping sequence $CHS_1$ comprising M time slots, each time slot having a corresponding RF channel frequency, and the RF channel frequency in each time slot being selected from a set of N RF channel frequencies. The first compatible hopping sequence $CHS_1$ may for example be generated by randomly selecting a first seed value from a range of integer seed values from 0 to 255 and using an LFSR with the first seed value to generate the first compatible hopping sequence $CHS_1$.

The method comprises setting a compatible hopping sequence found index y = 1 at step 112.

The method comprises selecting a first value for a candidate hopping sequence index x by setting the candidate hopping sequence index x = 1 at step 113.

If it is determined at step 114 that x is not equal to P, wherein P is an integer greater than or equal to S, then the method continues to step 115 comprising using the hopping sequence index x to generate a candidate hopping sequence $HS_x$ comprising M time slots, each time slot having a corresponding RF channel frequency, and the RF channel frequency in each time slot being selected from a set of N RF channel frequencies.

The method further comprises steps 116, 120, 122, 124, 126, 128, and 130 which together implement the following conditional logic statement.

If:

the candidate hopping sequence $HS_x$ and any of the previously generated compatible hopping sequences $CHS_1$ ... $CHS_y$ have the same RF channel frequency in the same time slot at step 120 or the candidate hopping sequence $HS_x$ and any of the previously generated compatible hopping sequences $CHS_1$ ... $CHS_y$ have the same RF channel frequency in adjacent time slots at steps 122 or 124,

then:

generate the next value of the candidate hopping sequence index x by incrementing the value of the candidate hopping sequence index x at step 116 and return to step 114;

else:

increment the compatible hopping sequence found index y at step 126 and identify the candidate hopping sequence $HS_x$ as the $y^{th}$ compatible hopping sequence $CHS_y$ at step 128; and

if y is not equal to S at step 130, then generate the next value of the candidate hopping sequence index x by incrementing the value of the candidate hopping sequence index x at step 116 and return to step 114.

More specifically, step 122 comprises:

determining a first time-shifted candidate hopping sequence $HS_{xR}$ wherein the RF channel frequency in each time slot of the first time-shifted candidate hopping

sequence $HS_{xR}$ except the first time slot of the first time-shifted candidate hopping sequence $HS_{xR}$ corresponds to the RF channel frequency in the preceding time slot of the candidate hopping sequence $HS_x$ and wherein the RF channel frequency in the first time slot of the first time-shifted candidate hopping sequence $HS_{xR}$ comprises the RF channel frequency in the last time slot of the candidate hopping sequence $HS_x$; and

determining whether the RF channel frequency in each time slot of the first time-shifted candidate hopping sequence $HS_{xR}$ is the same as the RF channel frequency in the corresponding time slot of each of the previously generated compatible hopping sequences $CHS_1$ ... $CHS_y$.

Similarly, step 124 comprises:

determining a second time-shifted candidate hopping sequence $HS_{xL}$ wherein the RF channel frequency in each time slot of the second time-shifted candidate hopping sequence $HS_{xL}$ except the last time slot of the second time-shifted candidate hopping sequence $HS_{xL}$ corresponds to the RF channel frequency in the next successive time slot of the candidate hopping sequence $HS_x$ and wherein the RF channel frequency in the last time slot of the second time-shifted candidate hopping sequence $HS_{xL}$ comprises the RF channel frequency in the first time slot of the candidate hopping sequence $HS_x$; and

determining whether the RF channel frequency in each time slot of the second time-shifted candidate hopping sequence $HS_{xL}$ is the same as the RF channel frequency in the corresponding time slot of each of the previously generated compatible hopping sequences $CHS_1$ ... $CHS_y$.

If y is equal to S at step 130, then a complete set of S compatible hopping sequences $CHS_1$ ... $CHS_S$ is output at step 132.

If it is determined at step 114 that x is equal to P, then as indicated at step 136, a different seed value may be selected at step 110 and the method of FIG. 5 may be repeated or at least one of P, M and N may be increased and the method of FIG. 5 may be repeated until y = S at step 130 and a complete set of S compatible hopping sequences $CHS_1$ ... $CHS_S$ is found at step 132 or until it is not possible to generate any more candidate hopping sequences $HS_x$ at step 115 which are different to any of the candidate hopping sequences $HS_x$ which were previously generated at step 115.

One of skill in the art will understand that in the method of FIG. 5, each candidate hopping sequence $HS_x$ is generated “on-the-fly” at step 115 until a set of S compatible hopping sequences is found. In a variant of the method of FIG. 5, instead of generating each candidate hopping sequences $HS_x$ “on-the-fly” at step 115, the method comprises

initially generating P candidate hopping sequences $HS_x$ and using the hopping sequence index x to select a different one of the candidate hopping sequences $HS_x$ from among the P generated hopping sequences at step 115, and then determining whether there exists one or more sets of S compatible hopping sequences from among the P generated candidate hopping sequences $HS_x$, wherein none of the hopping sequences of each set of S compatible hopping sequences have the same RF channel frequency in the same time slot and none of the hopping sequences of each set of S compatible hopping sequences have the same RF channel frequency in adjacent time slots, wherein P is an integer greater than or equal to three. P may, for example, be "255". In such a variant of the method of FIG. 5, one of the P generated candidate hopping sequences $HS_x$ is chosen as the first compatible hopping sequence $CHS_1$ at step 110 and each of the other P generated candidate hopping sequences $HS_x$ is compared one at a time with each of the preceding compatible hopping sequences $CHS_1$ ... $CHS_y$ at steps 120, 122 and 124 until all P generated candidate hopping sequences $HS_x$ have been compared one at a time with each of the preceding compatible hopping sequences $CHS_1$ ... $CHS_y$ or until a set of S compatible hopping sequences $CHS_1$ ... $CHS_S$ is determined at step 132.

By analogy with the method of generating different sets of three compatible hopping sequences for each hopping sequence ID number described above with reference to FIG. 4, it should also be understood that the method of FIG. 5, or the variant of the method of FIG. 5, may be repeated for each different seed value in a range of seed values to generate one or more sets of S compatible hopping sequences. All different sets of S compatible hopping sequences which include a given hopping sequence may then be identified from among the generated one or more sets of S compatible hopping sequences.

FIG. 6 shows a method for identifying whether the time synchronized channel hopping sequences of a given set of S time synchronized channel hopping sequences are compatible with one another for the transmission and/or reception of S wireless RF signals at S neighboring wireless RF transceivers, wherein each hopping sequence comprises M time slots, each time slot having a corresponding RF channel frequency, and the RF channel frequency in each time slot being selected from a set of N RF channel frequencies, and wherein the method comprises:

identifying that the set of S hopping sequences are compatible with one another if none of the hopping sequences of the set of S hopping sequences have the same RF channel frequency in the same time slot and none of the hopping sequences of the set of S hopping sequences have the same RF channel frequency in adjacent time slots,

wherein S, M and N are integers, and S is greater than or equal to two.

FIG. 7 shows the results of the method of FIG. 6 when applied to the three known hopping sequences identified by the hopSeqId values "1", "2" and "3" in FIG. 2 i.e. when S is 3, M is 64 and N is 128. One of ordinary skill in the art will understand that the values shown in FIG. 7 correspond to the RF channel frequencies highlighted in FIG. 2.

Although embodiments of the present disclosure have been described in terms as set forth above, it should be understood that these embodiments are illustrative only and that the claims are not limited to these embodiments. Those skilled in the art will understand that various modifications may be made to the described embodiments without departing from the scope of the appended claims. For example, in the method illustrated in FIGS. 3 and 4, any candidate TSCH sequence $HS_x$ is rejected if the candidate hopping sequence $HS_x$ has the same RF channel frequency in the same time slot as the first or second hopping sequences, or if the candidate hopping sequence $HS_x$ has an RF channel frequency in a time slot which is the same as an RF channel frequency in an adjacent time slot of the first or second sequences. In an alternative method, any candidate hopping sequence $HS_x$ may be rejected if the candidate hopping sequence $HS_x$ has the same RF channel frequency in the same time slot as the first or second hopping sequences, if the candidate hopping sequence $HS_x$ has an RF channel frequency in a time slot which is the same as an RF channel frequency in an adjacent time slot of the first or second hopping sequences, or if the candidate hopping sequence $HS_x$ has an RF channel frequency in a time slot which is the same as an RF channel frequency in a non-adjacent time slot of the first or second hopping sequences. For example, any candidate hopping sequence $HS_x$ may be rejected if the candidate hopping sequence $HS_x$ has the same RF channel frequency in the same time slot as the first or second hopping sequences, if the candidate hopping sequence $HS_x$ has an RF channel frequency in a time slot which is the same as an RF channel frequency in an adjacent time slot of the first or second hopping sequences, or if the candidate hopping sequence $HS_x$ has an RF channel frequency in a time slot which is the same as an RF channel frequency in a time-shifted time slot of the first or second hopping sequences, wherein the time-shifted time slot is shifted by two or more time slots.

In the foregoing methods, the hopping sequence ID number for each candidate hopping sequence $HS_x$ is generated by selecting a first integer value for the hopping sequence ID number, such as $x = 0$ in FIG. 3 or $x = 1$ in FIG. 5, and then generating the next value for the hopping sequence ID number x for each subsequent candidate hopping sequence $HS_x$ after the first candidate hopping sequence $HS_1$ by incrementing

the value of the preceding hopping sequence ID number x by one. In general, any integer value may be selected for the first value of the hopping sequence ID number x. Moreover, generating the hopping sequence ID number x for each candidate hopping sequence $HS_x$ after the first candidate hopping sequence $HS_1$ may comprise performing a mathematical operation on the value of the preceding hopping sequence ID number to generate an integer value of the hopping sequence ID number x for each candidate hopping sequence $HS_x$ after the first candidate hopping sequence $HS_1$. For example, generating the value of the hopping sequence ID number x for each subsequent candidate hopping sequence $HS_x$ after the first candidate hopping sequence $HS_1$ may comprise incrementing the value of the preceding hopping sequence ID number by any integer number.

In the foregoing methods, the first hopping sequence ID number is randomly selected from a range of integer values from 0 to 255. In other embodiments, the first hopping sequence ID number may be randomly selected from a different range of integer values. In other embodiments, the first hopping sequence ID number may be predetermined, for example the first hopping sequence ID number may be selected arbitrarily from a range of integer values from 0 to 255. For example, the first hopping sequence ID number may be selected to be zero, like at step 12 of FIG. 3, or the first hopping sequence ID number may be selected to be one, like at step 113 of FIG. 5.

Generating each candidate hopping sequence $HS_x$ may comprise generating each candidate hopping sequence $HS_x$ so that each candidate hopping sequence $HS_x$ is different from all of the other generated candidate hopping sequences $HS_x$.

The method may comprise generating all possible sets of S compatible hopping sequences for each first seed value of a plurality of different first seed values, for example for an entire range of different first seed values from 0 to 255.

If any method described above results in the generation of a plurality of S compatible hopping sequences, the method may further comprise selecting one of the sets of S compatible hopping sequences for transmitting and/or receiving wireless RF signals at the S neighboring wireless RF transceivers. The method may comprise selecting one of the sets of S compatible hopping sequences in a deterministic manner e.g. the method may comprise selecting the first found set of S compatible hopping sequences or the method may comprise selecting the set of S compatible hopping sequences having the lowest seed value or the highest seed value. The method may comprise selecting one of the sets of S compatible hopping sequences randomly or

arbitrarily. The method may comprise selecting one of the sets of S compatible hopping sequences manually.

Although the wireless RF communication device 2 is described above as a wireless RF network gateway device, the wireless RF communication device 2 is not limited to a wireless RF network gateway device and may be a wireless RF communication device of any kind.

Although the wireless RF communication device 2 includes three neighboring TSCH wireless RF transceivers 4 located within the housing 3, in other wireless RF communication devices the number of neighboring TSCH wireless RF transceivers 4 located within the housing 3 may be two or may be greater than three.

Moreover, the methods described above are not limited to the case where the neighboring TSCH wireless RF transceivers are located within the same housing. In variants of the methods described above, the neighboring TSCH wireless RF transceivers may be located in different housings and/or may be located in proximity to each other, for example within a predetermined range of each other. The neighboring TSCH wireless RF transceivers may be located in the same room and/or within the same building.

The method may comprise identifying one or more neighboring TSCH wireless RF transceivers, for example based on a strength of one or more respective wireless RF signals received from the one or more neighboring TSCH wireless RF transceivers. One or more of the TSCH wireless RF transceivers may be configured to identify one or more neighboring TSCH wireless RF transceivers, for example based on a strength of one or more respective wireless RF signals received from the one or more neighboring TSCH wireless RF transceivers.

The method may comprise identifying one or more neighboring TSCH wireless RF transceivers located within a predetermined range. One or more of the TSCH wireless RF transceivers may be configured to identify one or more neighboring TSCH wireless RF transceivers located within the predetermined range.

Each feature disclosed or illustrated in the present specification may be incorporated in any embodiment, either alone, or in any appropriate combination with any other feature disclosed or illustrated herein. In particular, one of ordinary skill in the art will understand that a selection of some but not all of the features of any embodiment of the present disclosure described above may produce effects or provide advantages when used in isolation from the other feature(s) of the same embodiment. One of ordinary skill in the art will understand that one or more of the features of any embodiment

of the present disclosure may produce effects or provide advantages when used in isolation from one or more of the other features of the same embodiment. One of ordinary skill in the art will also understand that different combinations of the features of the embodiments are possible other than the specific combinations of the features of the embodiments described above.

The skilled person will understand that in the preceding description and appended claims, positional terms such as 'above', 'along', 'side', etc. are made with reference to the accompanying drawings. These terms are used for ease of reference but are not intended to be limiting in nature. These terms are therefore to be understood as referring to an object when in an orientation as shown in the accompanying drawings.

Use of the term "comprising" when used in relation to a feature of an embodiment of the present disclosure does not exclude other features or steps. Use of the term "a" or "an" when used in relation to a feature of an embodiment of the present disclosure does not exclude the possibility that the embodiment may include a plurality of such features.

The use of reference signs in the claims should be construed to be non-limiting to the scope of the claims.

**CLAIMS**

1. A method for use in determining a set of S compatible time-synchronized channel hopping sequences for transmitting and/or receiving wireless RF signals at S neighboring wireless RF transceivers, the method comprising:

generating at least S hopping sequences, each hopping sequence comprising M time slots, each time slot having a corresponding RF channel frequency, and the RF channel frequency in each time slot being selected from a set of N RF channel frequencies; and

determining whether there exists one or more sets of S compatible hopping sequences from among the at least S generated hopping sequences, wherein none of the hopping sequences of each set of S compatible hopping sequences have the same RF channel frequency in the same time slot and none of the hopping sequences of each set of S compatible hopping sequences have the same RF channel frequency in adjacent time slots,

wherein S, M and N are integers, and S is greater than or equal to two.

2. The method as claimed in claim 1, wherein each time slot of each generated hopping sequence has a different RF channel frequency to the RF channel frequency of each of the other times slots of the same generated hopping sequence.

3. The method as claimed in claim 1, wherein generating the at least S hopping sequences comprises using a Linear Feedback Shift Register with at least S different hopping sequence ID numbers as seeds.

4. The method as claimed in claim 3, wherein the Linear Feedback Shift Register is configured so that for each different hopping sequence ID number, the Linear Feedback Shift Register generates a different hopping sequence.

5. The method as claimed in claim 3, wherein the Linear Feedback Shift Register is configured so that each time slot of each generated hopping sequence has a different RF channel frequency to the RF channel frequency of each of the other times slots of the same generated hopping sequence.

6. The method as claimed in claim 1, wherein generating the at least S hopping sequences and determining whether there exists one or more sets of S compatible hopping sequences from among the at least S generated hopping sequences comprises generating P hopping sequences and then determining whether there exists one or more sets of S compatible hopping sequences from among the P generated hopping sequences, wherein P is an integer greater than or equal to S.

7. The method as claimed in claim 6,

i) wherein generating the at least S hopping sequences comprises generating P different hopping sequences, each generated hopping sequence comprising M time slots, each time slot having a corresponding RF channel frequency, and the RF channel frequency in each time slot being selected from the set of N RF channel frequencies, wherein P is an integer greater than or equal to S; and

ii) wherein determining whether there exists one or more sets of S compatible hopping sequences from among the at least S generated hopping sequences comprises:

iii) selecting a first compatible hopping sequence $CHS_1$ from among the P different generated hopping sequences;

iv) selecting a hopping sequence $HS_x$ from among the P different generated hopping sequences;

v) identifying the selected hopping sequence $HS_x$ as a $y^{th}$ compatible hopping sequence $CHS_y$ if:

the selected hopping sequence $HS_x$ and any of the previously generated compatible hopping sequences $CHS_1$ ... $CHS_{y-1}$ do not have the same RF channel frequency in the same time slot; and

the hopping sequence $HS_x$ and any of the previously generated compatible hopping sequences $CHS_1$ ... $CHS_{y-1}$ do not have the same RF channel frequency in adjacent time slots; and

vi) repeating steps iv) and v) until a set of S compatible hopping sequences $CHS_1$ ... $CHS_S$ is identified or until all of the P different generated hopping sequences have been selected.

8. The method as claimed in claim 7, wherein determining whether the hopping sequence $HS_x$ and any of the previously generated compatible hopping sequences $CHS_1$

... $CHS_{y-1}$ do not have the same RF channel frequency in adjacent time slots at step v) comprises:

determining a first time-shifted hopping sequence $HS_{xR}$ wherein the RF channel frequency in each time slot of the first time-shifted hopping sequence $HS_{xR}$ except the first time slot of the first time-shifted hopping sequence $HS_{xR}$ corresponds to the RF channel frequency in the preceding time slot of the hopping sequence $HS_x$ and wherein the RF channel frequency in the first time slot of the first time-shifted hopping sequence $HS_{xR}$ comprises the RF channel frequency in the last time slot of the hopping sequence $HS_x$;

determining whether the RF channel frequency in each time slot of the first time-shifted hopping sequence $HS_{xR}$ is the same as the RF channel frequency in the corresponding time slot of each of the previously generated compatible hopping sequences $CHS_1$ ... $CHS_{y-1}$;

determining a second time-shifted hopping sequence $HS_{xL}$ wherein the RF channel frequency in each time slot of the second time-shifted hopping sequence $HS_{xL}$ except the last time slot of the second time-shifted hopping sequence $HS_{xL}$ corresponds to the RF channel frequency in the next successive time slot of the hopping sequence $HS_x$ and wherein the RF channel frequency in the last time slot of the second time-shifted hopping sequence $HS_{xL}$ comprises the RF channel frequency in the first time slot of the hopping sequence $HS_x$; and

determining whether the RF channel frequency in each time slot of the second time-shifted hopping sequence $HS_{xL}$ is the same as the RF channel frequency in the corresponding time slot of each of the previously generated compatible hopping sequences $CHS_1$ ... $CHS_{y-1}$.

9. The method as claimed in claim 7, comprising, responsive to determining that all of the P different generated hopping sequences have been selected at step vi), increasing at least one of P, M and N, and repeating steps i) – vi) until a set of S compatible hopping sequences is identified or until it is not possible to generate a set of P different hopping sequences at step i).

10. The method as claimed in claim 1, wherein generating the at least S hopping sequences and determining whether there exists one or more sets of S compatible hopping sequences from among the at least S generated hopping sequences comprises:

i) generating a first compatible hopping sequence $CHS_1$ comprising M time slots, each time slot having a corresponding RF channel frequency, and the RF channel frequency in each time slot being selected from the set of N RF channel frequencies;

ii) generating a hopping sequence $HS_x$ comprising M time slots, each time slot having a corresponding RF channel frequency, and the RF channel frequency in each time slot being selected from the set of N RF channel frequencies, wherein the generated hopping sequence $HS_x$ is different to any previously generated hopping sequence;

iii) identifying the generated hopping sequence $HS_x$ as a $y^{th}$ compatible hopping sequence $CHS_y$ if:

the hopping sequence $HS_x$ and any of the previously generated compatible hopping sequences $CHS_1$ ... $CHS_{y-1}$ do not have the same RF channel frequency in the same time slot, and

the hopping sequence $HS_x$ and any of the previously generated compatible hopping sequences $CHS_1$ ... $CHS_{y-1}$ do not have the same RF channel frequency in adjacent time slots, and

iv) repeating steps ii) and iii) until a set of S compatible hopping sequences $CHS_1$ ... $CHS_S$ is identified or until P different hopping sequences have been generated, wherein P is an integer greater than or equal to S.

11. The method as claimed in claim 10, wherein determining whether the hopping sequence $HS_x$ and any of the previously generated compatible hopping sequences $CHS_1$ ... $CHS_{y-1}$ do not have the same RF channel frequency in adjacent time slots at step iv) comprises:

determining a first time-shifted hopping sequence $HS_{xR}$ wherein the RF channel frequency in each time slot of the first time-shifted hopping sequence $HS_{xR}$ except the first time slot of the first time-shifted hopping sequence $HS_{xR}$ corresponds to the RF channel frequency in the preceding time slot of the hopping sequence $HS_x$ and wherein the RF channel frequency in the first time slot of the first time-shifted hopping sequence $HS_{xR}$ comprises the RF channel frequency in the last time slot of the hopping sequence $HS_x$;

determining whether the RF channel frequency in each time slot of the first time-shifted hopping sequence $HS_{xR}$ is the same as the RF channel frequency in the corresponding time slot of each of the previously generated compatible hopping sequences $CHS_1$ ... $CHS_{y-1}$;

determining a second time-shifted hopping sequence $HS_{xL}$ wherein the RF channel frequency in each time slot of the second time-shifted hopping sequence $HS_{xL}$ except the last time slot of the second time-shifted hopping sequence $HS_{xL}$ corresponds to the RF channel frequency in the next successive time slot of the hopping sequence $HS_x$ and wherein the RF channel frequency in the last time slot of the second time-shifted hopping sequence $HS_{xL}$ comprises the RF channel frequency in the first time slot of the hopping sequence $HS_x$; and

determining whether the RF channel frequency in each time slot of the second time-shifted hopping sequence $HS_{xL}$ is the same as the RF channel frequency in the corresponding time slot of each of the previously generated compatible hopping sequences $CHS_1 \ldots CHS_{y-1}$.

12. The method as claimed in claim 10, comprising, responsive to determining that P different hopping sequences have been generated at step iv), increasing at least one of P, M and N, and repeating steps i) – iv) until a set of S compatible hopping sequences is identified or until it is not possible to generate a hopping sequence $HS_x$ at step ii) which is different to any previously generated hopping sequences.

13. The method as claimed in claim 1, wherein S is equal to three or more.

14. The method as claimed in claim 1, wherein at least one of:
M is less than or equal to N;
M is 64; or
N is 64 or 128.

15. The method as claimed in claim 1, wherein none of the hopping sequences of each set of S compatible hopping sequences have the same RF channel frequency in non-adjacent time slots, each pair of non-adjacent time slots being offset from one another in time by a predetermined number of time slots which is greater than or equal to two, for example wherein the predetermined number of time slots is two or three.

16. A method of wireless RF communication comprising:

the method for use in determining a set of S compatible time-synchronized channel hopping sequences for transmitting and/or receiving wireless RF signals at S neighboring wireless RF transceivers as claimed in claim 1,

wherein the method of wireless RF communication further comprises:

in response to determining that there exists one or more sets of S compatible hopping sequences from among the at least S generated hopping sequences, selecting one of the one or more sets of S compatible hopping sequences for transmitting and/or receiving wireless RF signals at the S neighboring wireless RF transceivers; and

using the hopping sequences of the selected set of S compatible hopping sequences at respective wireless RF transceivers of the S neighboring wireless RF transceivers to transmit and/or receive respective wireless RF signals at the S neighboring wireless RF transceivers.

17. The method of wireless RF communication of claim 16, wherein using the hopping sequences of the selected set of S compatible hopping sequences at respective wireless RF transceivers of the S neighboring wireless RF transceivers to transmit and/or receive respective wireless RF signals at the S neighboring wireless RF transceivers comprises repeatedly using the hopping sequences of the selected set of S compatible hopping sequences at respective wireless RF transceivers of the S neighboring wireless RF transceivers to transmit and/or receive respective wireless RF signals at the S neighboring wireless RF transceivers so that the RF channel frequency used by each of the S neighboring wireless RF transceivers is cycled repeatedly through all of the RF channel frequencies of the corresponding hopping sequence from the first time slot to the $M^{th}$ time slot during transmission and/or reception of the corresponding wireless RF signal.

18. A wireless RF communication device such as a wireless RF network gateway device, wherein the wireless RF communication device comprises S neighboring wireless RF transceivers, wherein the S wireless RF transceivers are configured to use respective hopping sequences of a set of S compatible hopping sequences selected from the one or more sets of S compatible hopping sequences determined using the method as claimed in claim 1 to transmit and/or receive respective wireless RF signals.

19. A method for identifying whether the time synchronized channel hopping sequences of a set of S time synchronized channel hopping sequences are compatible with one another for the transmission and/or reception of S wireless RF signals at S neighboring wireless RF transceivers, wherein each hopping sequence comprises M time slots, each time slot having a corresponding RF channel frequency, and the RF

channel frequency in each time slot being selected from a set of N RF channel frequencies, and wherein the method comprises:

identifying that the set of S hopping sequences are compatible with one another if none of the hopping sequences of the set of S hopping sequences have the same RF channel frequency in the same time slot and none of the hopping sequences of the set of S hopping sequences have the same RF channel frequency in adjacent time slots,

wherein S, M and N are integers, and S is greater than or equal to two.

20. A method of wireless RF communication comprising:

using the method as claimed in claim 19 to identify that a set of S time synchronized channel hopping sequences are compatible with one another for the transmission and/or reception of S wireless RF signals at S neighboring wireless RF transceivers; and

using the hopping sequences of the set of S compatible hopping sequences at respective wireless RF transceivers of the S neighboring wireless RF transceivers to transmit and/or receive respective wireless RF signals at the S neighboring wireless RF transceivers.