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Title	**Discussion on inter working between frame structure, co-existence procedures, and credit tokens based scheduling mechanisms**
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Re:	Call for Contributions, IEEE 802.16h Task Group on License-Exempt Coexistence, IEEE 802.16h-05/028
Abstract	Based on a simple illustrative example, this document addresses the possible inter working between the existing frame structure, co-existence procedures, and credit tokens based scheduling mechanisms currently described in the working draft document [1].
Purpose	Discuss/clarify the inter-working between the frame structure, co-existence procedures and credit tokens based scheduling mechanisms. This doc aims at serving as a basis for the group to discuss/agree on the underlying working assumptions and approach for 802.16h in this area.
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Discussion on inter working between frame structure, co-existence procedures, and credit tokens based scheduling mechanisms

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1 Introduction

Mechanisms for resources sharing are addressed by different mechanisms into different parts of the working draft document [1]. In particular, this includes the frame structure (interference free, master sub frames), co-existence procedures (co-existence protocol, community, radio signature, CTS) and cooperation between networks (credit tokens based scheduling mechanisms). Section 15.2.1.1.2 [1] describes different frame structure options. However, no details are provided on the way radio resources are partitioned between BS (resp. SS) by these options within each interference free/master sub frame. Provided this missing information, the relationship between the frame structure, co-existence procedures, and credit tokens based scheduling mechanisms is currently unclear in the working draft document [1]. With respect to this, this contribution proposes a simple illustrative example using basic resources partitioning between BS (resp. SS) in the master sub frame. Based on this resources partitioning, the contribution then attempts to figure out the high level principles for the inter-working between the frame structure (interference free, master sub frames), co-existence procedures (co-existence protocol, community, radio signature, CTS) and cooperation between networks (credit tokens based scheduling mechanisms). It should be noted that this contribution is based on a simple example and basic working assumptions on the resources partitioning within each master sub-frame. With respect to this, this contribution only intends to provide an illustrative material for the task group in order to discuss this inter-working and agree on the general principles before moving to the details that will be needed to be developed then. Also, note this example is not limitative and does not preclude different usages of the different existing mechanisms (related to frame structure, co-existence procedures and cooperation between networks) already defined in the working draft document [1]. Finally, this example also serves as basis for clarifying some open questions raised during the previous meeting (Session #40) related to the usage of the credit tokens based mechanisms [2].

2 Background

Provided the ambiguity on the current definition of a network (one single BS, several BSs?) and of an operator in the current version of the working draft document [1], the definition of an interference free or a master sub-frame is also ambiguous. In particular, one master sub-frame is currently periodically dedicated to one NW: does that mean to one or several BSs?. Also it is unclear whether each NW is operated by the same operator or different operators. With respect to this, it is unclear to who the radio resources (time*frequency) of a given sub frame is assigned to (to one single BS?, to different BS?). In other terms, it is unclear how these radio resources are partitioned within a same master sub-frame. Along with this, two different levels of co-existence cases raise: self-coexistence (radio resources partitioning between BSs of a same NW), and inter NW co-existence (radio resources partitioning between BSs of different NWs operated by different operators). In the working draft document, it is unclear how these two co-existence cases are related to the current proposed frame structure, and these two cases might be tackled differently.

3 Scenario

This part describes a simple example for resources partitioning. The scenario considers two operators (LE_1 and LE_2). Each operator operates one single NW. Each NW is composed of 19 cells. It is assumed that each master sub-frame can support several BSs links (or SSs links) of a same NW operated by a same operator. Each NW is periodically assigned a nominal (access guarantee) master sub frame as depicted in Figure 1. Each master sub frame is composed of 21 BINs. A BIN is defined as a joint time/frequency resource unit. By default, each nominal sub frame is allocated with N BINs for the guaranteed access (for the sake of simplification, it is assumed the number of BINs per sub frame is the same for the DL and UL). In each sub frame of a given NW,

the BINs are partitioned among the BSs of a co-channel community of a given $BS_{i,j}$. $BS_{i,j}$ denotes the BS #j operated by LE_i. $SS_{i,j}$ denotes the SS operated by LE_i and attached to BS_j. The resources partitioning depicted for LE_1 in Figure 1 corresponds to the co-channel community of $BS_{1,1}$ in Figure 2. The co-channel community of $BS_{1,1}$ is composed of $BS_{1,2}$, $BS_{1,3}$, $BS_{1,4}$, $BS_{1,5}$, $BS_{1,6}$ and $BS_{1,7}$. In the example, initially each of these BSs is assigned with three BINs. Also, initially it is assumed that each $SS_{i,j}$ belonging to this community is also assigned with three BINs.

In the following, it is considered that:

LE_1 and LE_2 are co-located with a little spatial shift between the BSs of the two networks (Figure 1).

In DL (Figure 1 and Figure 1):

- $BS_{1,1}$, initially assigned with three BINs for DL operations, requires six more BINs to support additional DL traffic during δs time units from a given starting time. So the total demand for $BS_{1,1}$ is nine BINs (Figure 1) traffic during δs time units. With respect to this, at that time, $BS_{1,1}$ of LE_1 has a “renter” status (top of Figure 1).
- At the same time, some BSs of LE_2 are not fully loaded (e.g. $BS_{2,1}$, $BS_{2,2}$, $BS_{2,3}$, $BS_{2,4}$, $BS_{2,6}$, and $BS_{2,7}$). With respect to this, at that time, some BSs of LE_2 have an “offeror” status (bottom of Figure 1) for providing additional BINs to $BS_{1,1}$ of LE_1 during the master sub frame of LE_2.

In UL (Figure 1 and Figure 3):

- $BS_{1,1}$, initially assigned with three BINs for UL operations, requires four more BINs to support additional UL traffic during δs time units from a given starting time. So the total demand for $BS_{1,1}$ is seven BINs (Figure 3) traffic during δs time units. With respect to this, at that time, $BS_{1,1}$ of LE_1 has a “renter” status (top of Figure 1).
- At the same time, some BSs of LE_2 are not fully loaded (e.g. $BS_{2,2}$ and $BS_{2,7}$). With respect to this, at that time, some BSs of LE_2 have an “offeror” status (bottom of Figure 1) for providing additional BINs to $BS_{1,1}$ of LE_1 during the master sub frame of LE_2.

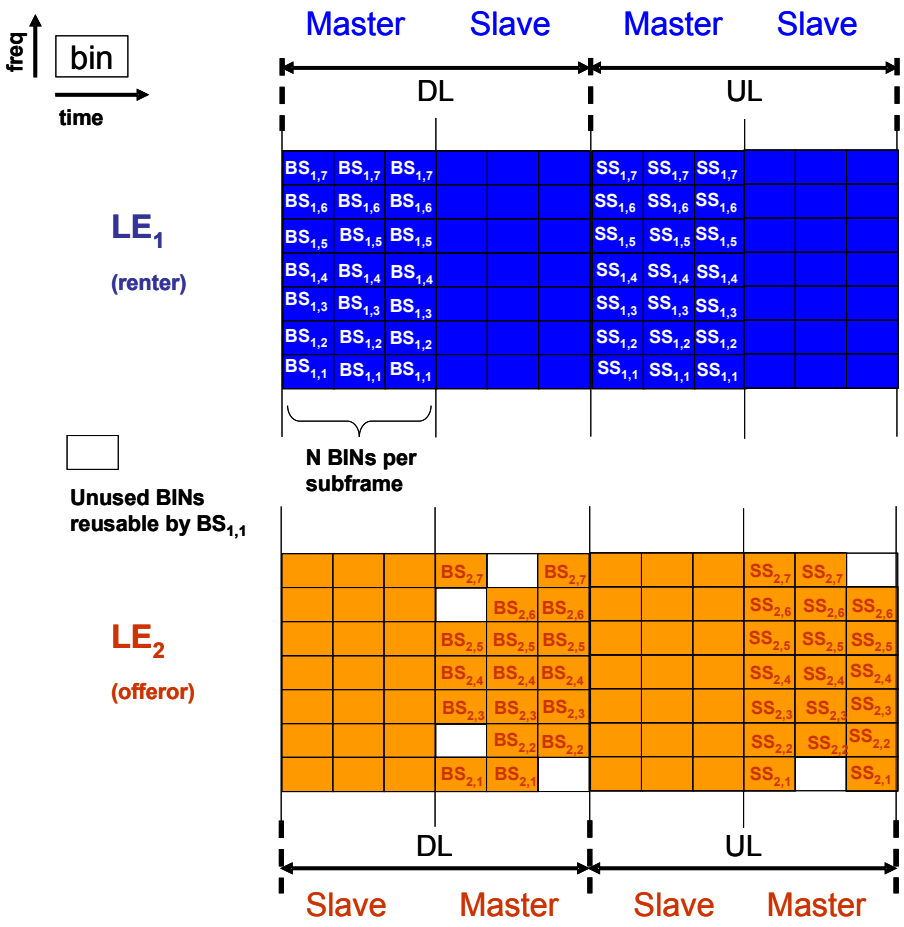

Figure 1: **Initial DL and UL resources (BINs) partitioning in the frame structure for LE_1 and LE_2**

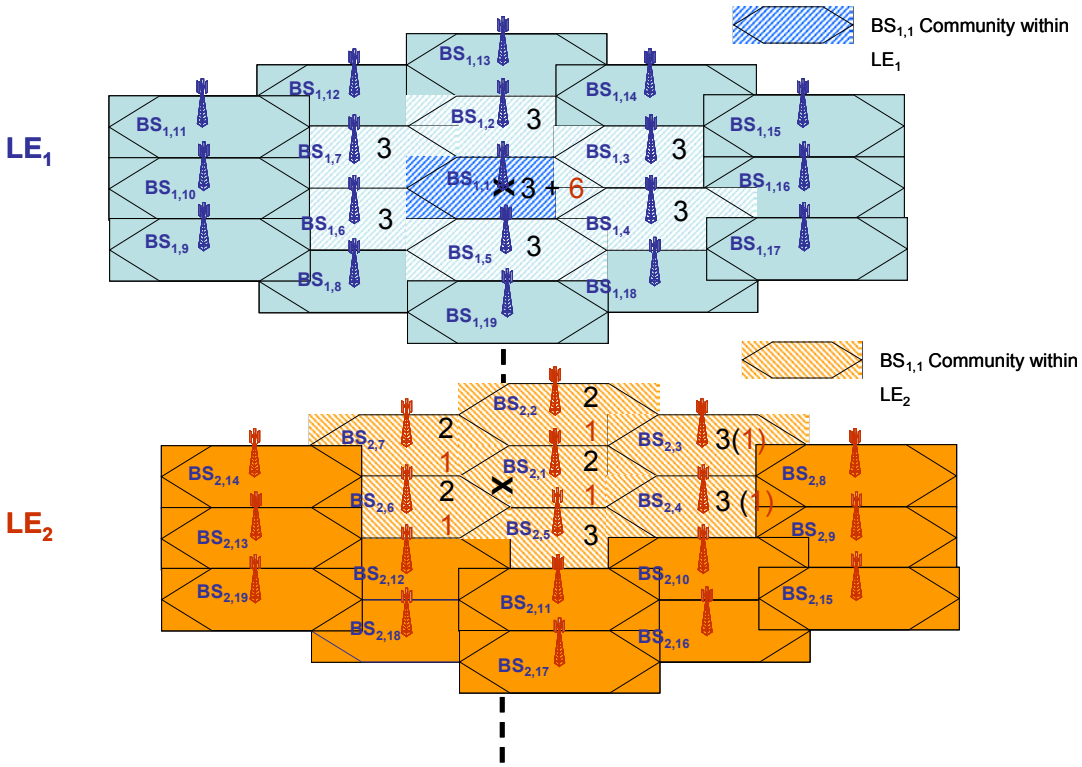

Figure 2: Initial BINs partitioning for $BS_{1,1}$ co-channel community in LE_1 in DL (top), and initial BINs partitioning for $BS_{1,1}$ co-channel community in LE_2 in DL (bottom)

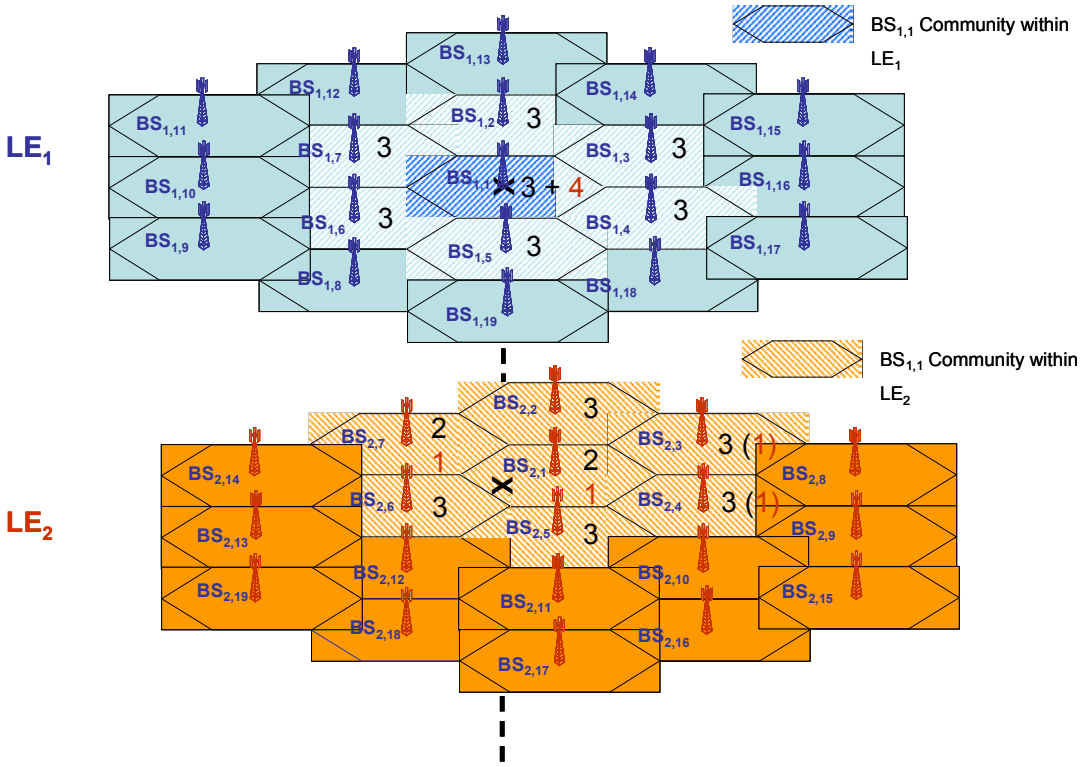

Figure 3: Initial BINs partitioning for $BS_{1,1}$ co-channel community in LE_1 in UL (top), and initial BINs partitioning for $BS_{1,1}$ co-channel community in LE_2 in UL (bottom)

4 Inter-working between frame structure, co-existence procedures and credit tokens based scheduling mechanisms

On the basis of the simple frame structure assumptions and associated scenario described in section 3, this section attempts to derive the main high level mechanisms to enable the inter-working of the existing co-existence procedures (co-existence protocol, community, radio signature, CTS) and credit tokens based scheduling mechanisms (section 15.7.1.2.6) of the working draft document [1]. As described in section 3, purpose is to assign additional resources (BINs) to $BS_{1,1}$ in both DL and UL during δs time units. With respect to this, $BS_{1,1}$ can search BINs within its co-channel community within LE_1, and/or within its co-channel community within LE_2.

4.1 Self co-existence

During the self co-existence procedure (respectively for DL and UL), steps can consist as follows (Figure 4):

$BS_{1,1}$ makes an estimate on the additional traffic to be supported by $BS_{1,1}$ during δs time units from a given starting time,

Based on this traffic estimate, $BS_{1,1}$ makes an estimate on the number of required BINs (N') to support this traffic,

Based on this number of BINs estimate (N'), $BS_{1,1}$ checks whether this amount of BINs is available within its co-channel community within LE_1. This checking is carried out by one or several existing co-existence procedures (co-existence protocol, community, radio signature, CTS) currently proposed in the working draft document (however, the inter working of these co-existence procedures remain to be clarified):

- In case N' BINs can be re-allocated within LE_1, BINs scheduling is performed within LE_1 to assign these BINs to $BS_{1,1}$,
- In case no sufficient number of BINs are available in LE_1, $BS_{1,1}$ has to explore reuse opportunities within its co-channel community within LE_2 (section 4.2),

In the above example, no BINs are available in $BS_{1,1}$ co-channel community within LE_1. So, no N' BINs can be re-allocated to $BS_{1,1}$ within LE_1 in both DL and UL. Indeed, all DL BINs are already all used (Figure 1) in both DL and UL. So, $BS_{1,1}$ has to explore DL and UL reuse opportunities within its co-channel community within LE_2.

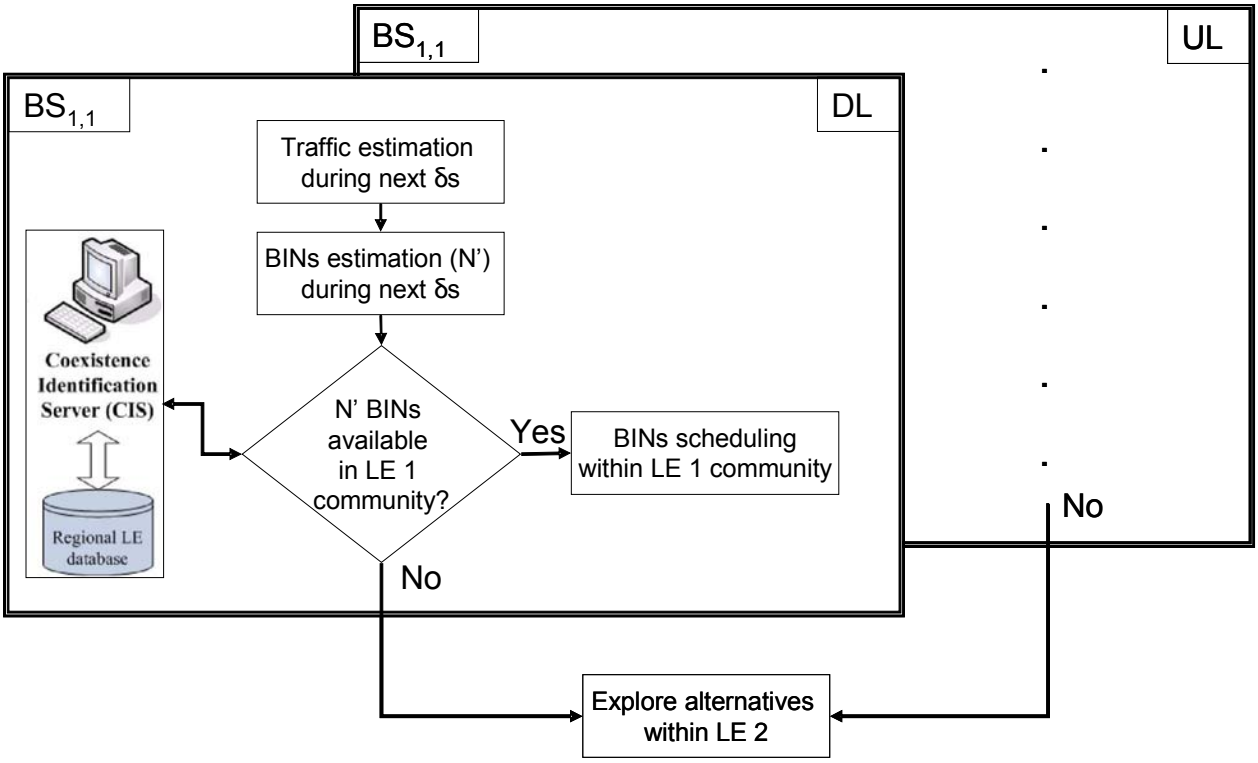

Figure 4: Self co-existence flow chart

4.2 Inter NW co-existence

Purpose of the inter NW co-existence procedures is to find out BINs reuse opportunities in another NW. In the particular scenario above, this means $BS_{1,1}$ has the possibility to explore reuse opportunities within its co-channel community within LE_2 and to be assigned possibly with these resources.

The inter NW co-existence procedures are split between the "exclusive sharing" and "non exclusive sharing" phase as depicted respectively in section 4.2.1 and 4.2.2.

4.2.1 Exclusive sharing

During the "exclusive sharing" procedure (respectively for DL and UL), steps can consist as follows (Figure 5):

$BS_{1,1}$ identifies its co-channel community within LE_2. This can be achieved with the co-existence protocol proposed in the working draft document [1],

Based on this information, the unused BINs in this community are identified. This can be achieved by one or several existing co-existence procedures (co-existence protocol, community, radio signature, CTS) currently proposed in the working draft document (however, the inter working of these co-existence procedures remain to be clarified),

Based on the previous information, $BS_{1,1}$ checks if some BINs are unused and available for its own operations:

- In case some BINs are available, the negotiation between involved BSs for this resource sharing is launched with the credit tokens based scheduling mechanisms,
- In case no BINs are available, $BS_{1,1}$ has to explore reuse opportunities ("non exclusive sharing") within its co-channel community within LE_2 (section 4.2.2),

In the above example, it can be seen (Figure 1) that some BINs are not used by some BS belonging to LE_2. In particular, in DL, four BINs are available during LE_2 DL master sub frame (one BIN in $BS_{2,1}$, one BIN in $BS_{2,2}$, one BIN in $BS_{2,6}$ and one BIN in $BS_{2,7}$). Each of these BSs ($BS_{2,1}$, $BS_{2,2}$, $BS_{2,6}$ and $BS_{2,7}$) can offer these BINs

for renting. These four BINs are candidate for reusability by $BS_{1,1}$. In a similar way, in UL, two BINs are available during LE_2 UL master sub frame (one BIN in $SS_{2,1}$ and one BIN in $SS_{2,7}$). Each of these BSs ($BS_{2,1}$ and $BS_{2,7}$) can offer these BINs for renting. These two BINs are candidate for reusability by $BS_{1,1}$.

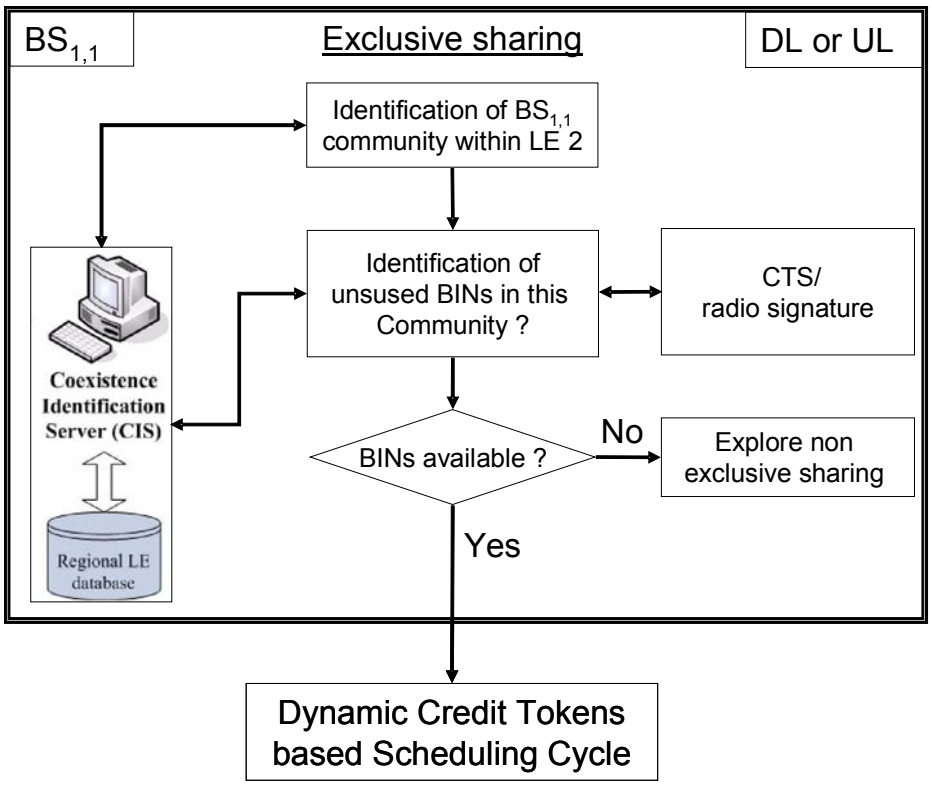

Figure 5: "Exclusive sharing phase" flow chart of the inter NW co-existence procedure

4.2.2 Non exclusive sharing

During the "non exclusive sharing" procedure (respectively for DL and UL), steps can consist as follows (Figure 6):

$BS_{1,1}$ identifies its co-channel community within LE_2. This can be achieved with the co-existence protocol proposed in the working draft document [1],

Based on this information, some BINs already used by some BSs in this community are identified to explore how $BS_{1,1}$ could reuse some of them provided that $BS_{1,1}$ does not interfere with the BS already using these BINs. In that case, a same BIN can be used simultaneously by two (or more) BSs belonging to the same co-channel community (non exclusive sharing). This exploration can be achieved by one or several existing co-existence procedures (co-existence protocol, community, radio signature, CTS) currently proposed in the working draft document (however, the inter working of these co-existence procedures remain to be clarified),

Based on the previous information, $BS_{1,1}$ checks if some BINs are unused and available for its own operations:

- In case some BINs are available, the negotiation between involved BSs for this resource sharing is launched with the credit tokens based scheduling mechanisms,
- In case no BINs are available, "non exclusive sharing" is not possible.

In the above example, it can be seen (Figure 8) that some BINs can be used by $BS_{1,1}$ although these BINs are already used by some BSs belonging to LE_2. In particular, in DL, two BINs are available during LE_2 DL master

sub frame (one BIN in $BS_{2,3}$ and one BIN in $BS_{2,4}$). Each of these BSs ($BS_{2,3}$ and $BS_{2,4}$) can offer these BINs for renting. These two BINs are candidate for reusability by $BS_{1,1}$. In a similar way, in UL, two BINs are available during LE_2 UL master sub frame (one BIN in $SS_{2,3}$ and one BIN in $SS_{2,4}$). Each of these BSs ($BS_{2,3}$ and $BS_{2,4}$) can offer these BINs for renting. These two BINs are candidate for reusability by $BS_{1,1}$.

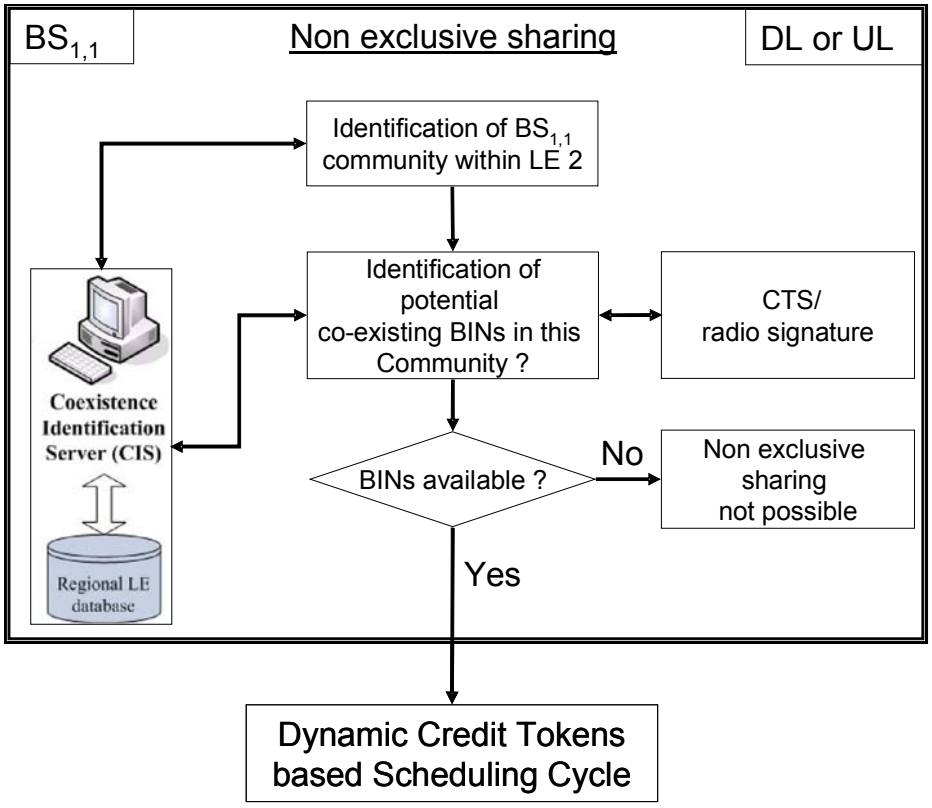

Figure 6: "Non exclusive sharing" phase flow chart of the inter NW co-existence procedure

4.3 Dynamic credit tokens based scheduling cycle

During the "Dynamic credit tokens based scheduling cycle" procedure (respectively for DL and UL), steps can consist as follows (Figure 7):

Sections 4.2.1 and 4.2.2 enable to identify the potential BSs candidates (on a "exclusive" or "non exclusive" resources sharing basis) for resources (BINs) offering to the renter $BS_{1,1}$. These BSs candidates ($BS_{2,1}$, $BS_{2,2}$, $BS_{2,3}$, $BS_{2,4}$, $BS_{2,6}$ and $BS_{2,7}$ in DL, $BS_{2,1}$,$BS_{2,3}$, $BS_{2,4}$ and $BS_{2,7}$ in UL) are within $BS_{1,1}$ co-channel community within LE_2, and are identified,

Based on this information, it is checked if the BSs that claim to be "offeror" candidates are actually master BS since only BS of master sub-frames can be "offeror". In order to validate this, a "security check" is performed with the co-existence protocol (use of data bases/servers). This step prevent slave BSs to qualify as master BSs.

Once the security check is validated, the different phases of the credit tokens based scheduling cycle are carried out:

- If the transaction is successful, the resources are granted to $BS_{1,1}$.
- If the transaction is not successful, no sharing occurs.

Note: It should be noted that the illustration is carried out for two operators, but it could be extended to more than two.

In case all transactions are successful (in both DL and UL), Figure 8 shows the final resources assignment for $BS_{1,1}$.

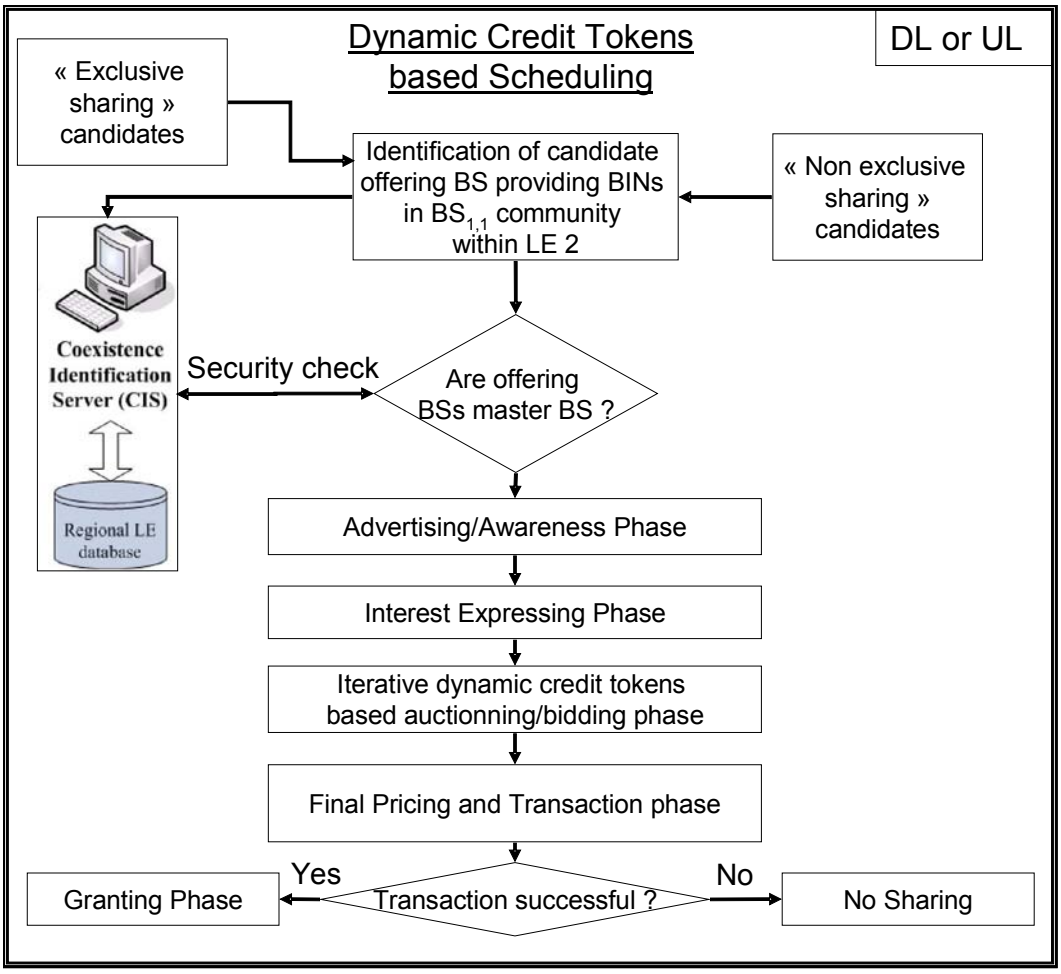

Figure 7: Dynamic credit tokens based scheduling flowchart

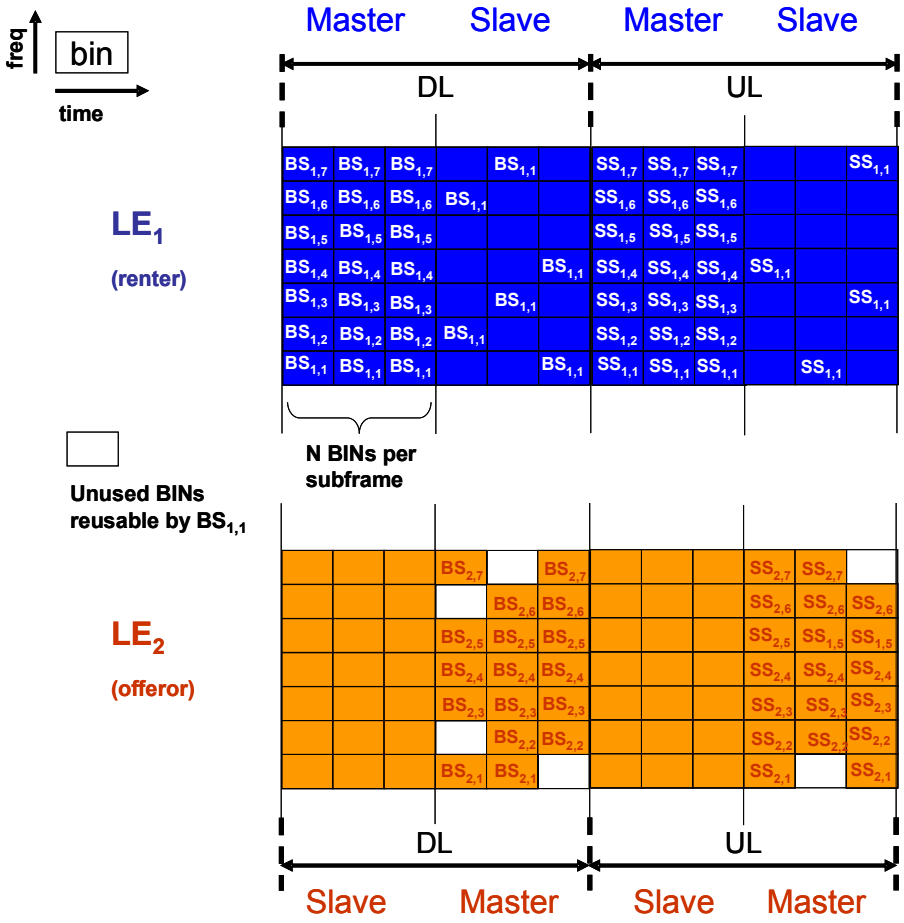

Figure 8: Final DL and UL resources (BINs) partitioning in the frame structure for LE_1 and LE_2

5 Conclusion

Given some basic assumptions on the resources (BINs) partitioning for the frame structure, this contribution has addressed how the frame structure, co-existence procedures (co-existence protocol, community, radio signature, CTS) and cooperation between networks (credit tokens based scheduling mechanisms) can ~~be~~ inter-work in a simple scenario. This contribution intends to provide an illustrative material for the task group in order to discuss this inter-working and agree on the general principles before moving to the details that will be needed to be developed then. Also, it would be worth defining (clarifying) the following two cases when addressing resources sharing: self co existence (resources sharing between BSs of a same NW) and inter NW co-existence ~~between LE systems~~ (resources sharing between BSs of different NWs operated by different operators). Finally, note this example is not limitative and does not preclude different usages of the different existing mechanisms (related to frame structure, co-existence procedures and cooperation between networks) already defined in the working draft document [1]. In particular, the credit tokens based scheduling mechanisms can also be applied for the self co-existence procedure.

References

[1] IEEE 802.16h-05/027 - pre- draft Working Document for P802.16h, 2005-12-02
[2] IEEE C802.16h-05/036r1 - Proposal for enhanced credit tokens based co-existence resolution and negotiation protocol, 2005-07-11