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Re:	Call for Contributions, IEEE 802.16h Task Group on License-Exempt Coexistence, IEEE 80216h-05/014
Abstract	Enhanced mechanisms proposal for a cooperative based co-existence resolution and negotiation protocol + text changes proposals in section 15.7.2.2.6
Purpose	Provide flexible mechanisms for a fair and efficient sharing of the common MAC frame
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Proposal for enhanced credit tokens based co-existence resolution and negotiation protocol

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1 Introduction

In the previous contribution [1], credit tokens based scheduling mechanisms for a cooperative based co-existence resolution and negotiation protocol have been proposed for two cases: (1) negotiation of the master nominal sub frames (interference free sub frames) length between master BSs, and (2) negotiation of co-channel master and slave sub frames transmissions for co-existence between master and slave BSs. The mechanism related to case (1) has been included within the section 15.7.2.2.6 of the section 15.7.2.2 ("Shared Radio Resource Management") of the IEEE 802.16h draft document [2]. This credit tokens based scheduling mechanism is static (one shot based). In order to provide additional flexibility and scalability, first purpose of this new contribution is to provide an enhanced mechanism by proposing a multi stages (iterative) mechanism for case (1). Additionally, during session #38, it has been agreed that only the text related to the mechanisms of case (1) has to be included in [2]. However, some text related to case (2) remains in [2]. As such, second purpose of this contribution is to propose text change in the existing text of the section 15.7.2.2.6 of [2] to remove the text irrelevant to case (1). The text related to the proposed enhanced mechanism and the text related to the text change proposals is intended for inclusion within the section 15.7.2.2.6 of the IEEE 802.16h draft document [2].

2 Background

As mentioned in the introduction section above, the current proposed (section 15.7.2.2.6 in [2]) credit tokens based scheduling mechanisms have some limitation in the sense these mechanisms are static. Indeed, in this current followed approach, the bidders BS_k submit independently a single bid from the beginning, without having new chances to bid for that auction. As such, each bidder BS_k has no chance to modify his bid to increase the value of this bid, and therefore to win the bid at the end. The contribution proposes enhancement to cope with this limitation by: (1) proposing a real time dynamic (iterative) credit tokens based auctioning/bidding cycle enabling the inter BS spectrum sharing in a distributed fashion; (2) proposing the mechanisms to support the different phases of the dynamic (iterative) credit tokens based auctioning cycle.

3 Proposal for enhanced credit tokens based co-existence resolution and negotiation protocol

The negotiation of the master nominal sub frames (interference free sub frames) length between master BSs is enabled by the credit tokens based scheduling mechanism. However, this mechanism currently proposed in section 15.7.2.2.6.3 is static. In order to provide additional flexibility and scalability, this new contribution enhances this mechanism by proposing a multi stages (iterative) mechanism. Text of this section 3 is intended to update/upgrade the existing text within the section 15.7.2.2.6.3.

3.1 Definition and notation

- BS_N denotes the BS belonging to the master NW_N,
- BS_k denotes the BS belonging to the slave NW_k,

- Each BS_k can dynamically make a bid $\mathbf{BS\_CT^{(n)}_k}$ at the n^{th} iteration. This bid corresponds to the amount of credit tokens per time unit corresponding to the BS_k during the n^{th} iteration of the bidding phase.
- Resource scheduling is carried out by an auction like mechanism. The auction type used for the scheduling is dynamic in time. The auction type used by the master NW_N is an ascending bid auction (open second price based scheduling). Starting from the reserved price auction **RPA**, the price of auction is successfully raised (at each iteration n) until the winning bidders remain.

3.2 Dynamic credit tokens based auctioning/bidding cycle

The contribution proposes a dynamic auctioning/bidding cycle between one BS_N of master NW_N and several BS_k of different slave NW_k. For the sake of simplicity, the cycle is illustrated (Figure 1 and Figure 2) for one BS_N and one BS_k of a given slave NW_k. The cycle is composed of different phases, and each phase can be composed of several sequences as follows.

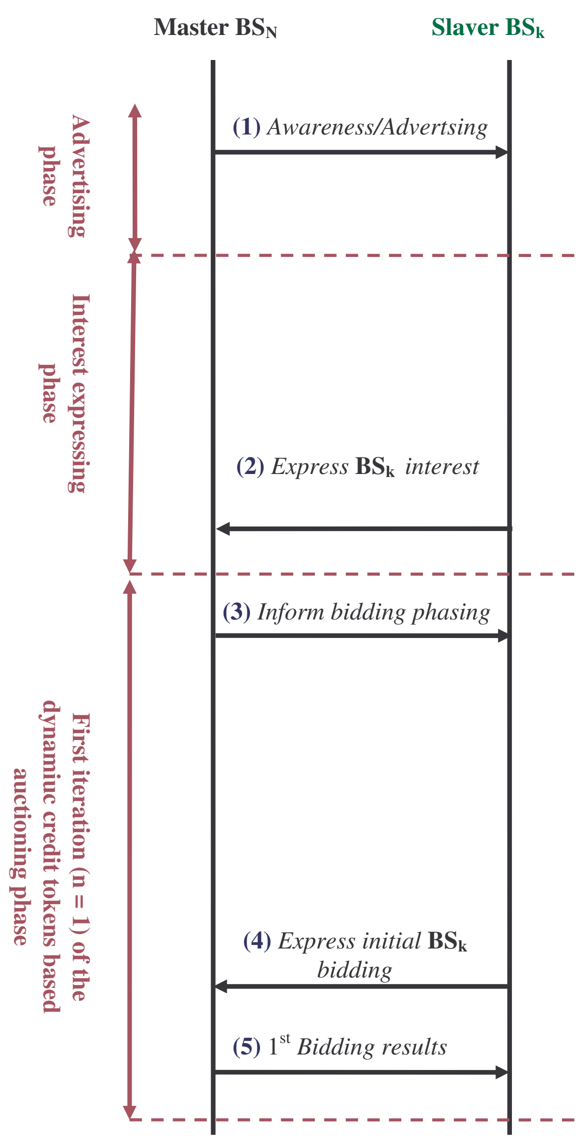

Figure 1: **Dynamic (iterative) credit tokens based auctioning cycle – (sequences (1) to (5))**

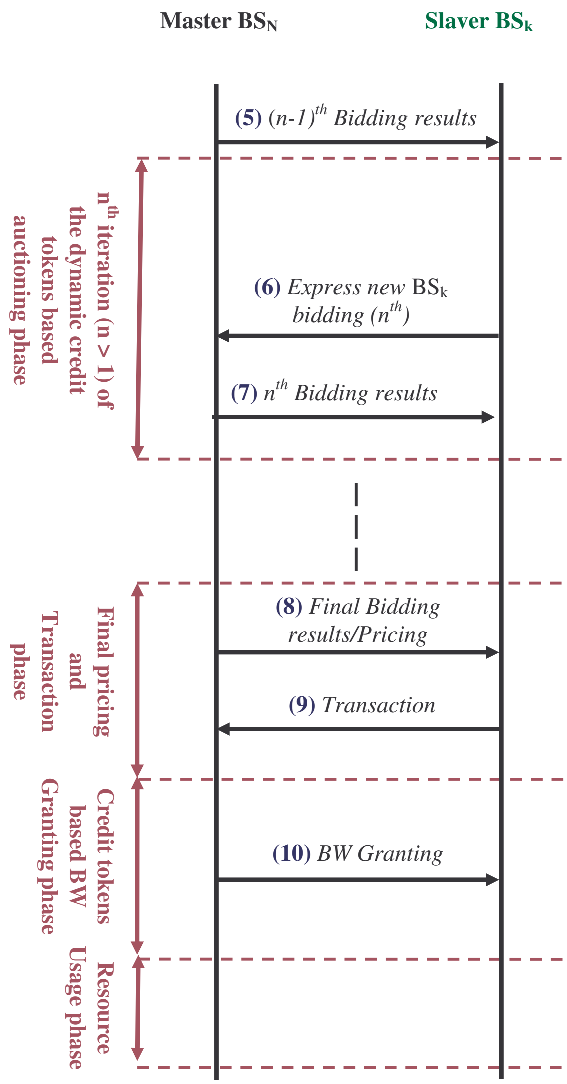

Figure 2: **Dynamic (iterative) credit tokens based auctioning cycle – (sequences (5) to (10))**

3.3 Enhanced negotiation mechanisms between master NWs

For each of the phase of the credit tokens based auctioning/bidding cycle presented in section 3.2, this section 3.3 describes the details of the enhanced mechanisms.

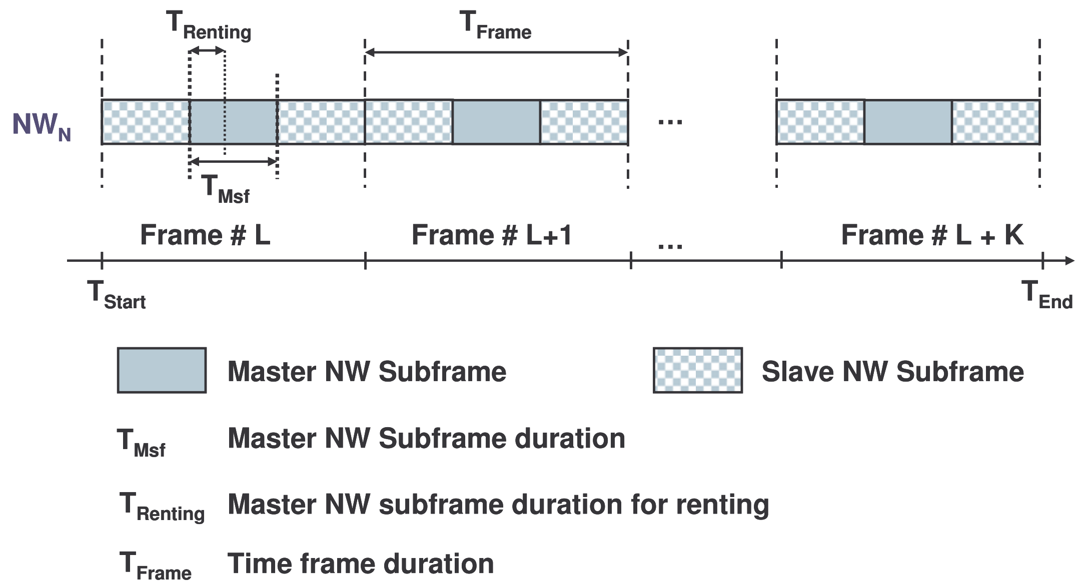

Figure h34: **Simplified MAC frame structure illustrating master NW sub-frame renting principle and associated notations**

Advertising/Awareness phase

This phase is composed of the single sequence (1) as follows:

- The master NW_N (seller) advertises that its periodic assigned master sub-frame is open for renting (Figure h34) from starting time $\mathbf{T_{Start}}$ to ending time $\mathbf{T_{End}}$ for a fraction ($\mathbf{T_{Renting}/T_{Msf}}$) of its master sub-frame duration $\mathbf{T_{Msf}}$. $\mathbf{T_{Renting} = T_{End\ Renting} - T_{Start\ Renting}}$.
- The master NW_N proposes a reserve price auction **RPA** for this renting. The **RPA** is expressed as a number of credit tokens per time unit.

Interest expressing phase

This phase is composed of the single sequence (2) as follows: each BS_k informs the master BS_N about its willingness (or not) to participate to the bidding. If the BS_k is interested, it communicates its $\mathbf{id_k}$ to the master BS_N.

First iteration (n = 1) of the credit tokens based auctioning/bidding phase

This phase is divided into 3 sequences as follows:

- In sequence (3), the master BS_N provides the following information to the slave BS_ks that have expressed the interest to participate to the bidding:
    - $\mathbf{T_{Start\ Bidding}}$: time from which the bidding phase will start,
    - $\mathbf{T_{End\ Bidding}}$: time at which the bidding phase will end ($\mathbf{T_{End\ Bidding} < T_{Start}}$),

  Note: For this first iteration (n = 1), the initial $\{\mathbf{id_k}\}$ is noted $\{\mathbf{id^{(1)}_k}\}$.
- In sequence (4), each BS_k provides the following information to BS_N: $\mathbf{BID^{(1)}_k = \{BS\_CT^{(1)}_k, x_k, T_{Start\ k}, T_{End\ k}\}}$ where:

- $\mathbf{BS\_CT^{(1)}_k}$ is the amount of bided credit tokens per time unit proposed by BS_k for the first iteration,
- x_k is the fraction of $T_{Renting}$ for which bid $\mathbf{BS\_CT^{(1)}_k}$ applies for,
- $[T_{Start\ k}, T_{End\ k}]$ is the time interval for which bid $\mathbf{BS\_CT^{(1)}_k}$ applies for. $[\mathbf{T_{Start\ k}}, \mathbf{T_{End\ k}}] \subset [\mathbf{T_{Start}}, \mathbf{T_{End}}]$.

- In sequence (5), BS_N performs the following action:
  - Given the set of intervals $\{[\mathbf{T_{Start\ k}}, \mathbf{T_{End\ k}}]\}$ received from different bidders $\{\mathbf{id^{(1)}_k}\}$, BS_N partitions $\{[\mathbf{T_{Start}}, \mathbf{T_{End}}]\}$ into contiguous time segments $\{\mathbf{TS_m}\}$. Each $\mathbf{TS_m}$ corresponds to a time window (integer number of $\mathbf{T_{Frame}}$) in which a subset of intervals of $\{[\mathbf{T_{Start\ k}}, \mathbf{T_{End\ k}}]\}$ overlap.
  - The different bidders $\{\mathbf{id^{(1)}_k}\}$ assigned to a given $\mathbf{TS_m}$ are identified by $\{\mathbf{id^{(1)}_{k,m}}\}$. $\{\mathbf{id^{(1)}_{k,m}}\}$ compete for each $\mathbf{TS_m}$. Each involved bidder $\mathbf{id^{(1)}_{k,m}}$ competes with his respective $\mathbf{BID^{(1)}_k}$.
  - Then, for each $\mathbf{TS_m}$, the master BS_N calculates the payoff $\mathbf{P^{(1)}_k = BS\_CT^{(1)}_k * x_k * T_{Renting} * N_{Frame\ m}}$ for each bidder k, and searches the subset $(\{\mathbf{id^{(1)}_{k,m}}\}_{selected})$ of $\{\mathbf{id^{(1)}_{k,m}}\}$ such as sum($\mathbf{x_k}$) = **1** and sum($\mathbf{P^{(1)}_k}$) is maximal. $\mathbf{N_{Frame\ m}}$ is the number of frames within $\mathbf{TS_m}$ ($\mathbf{N_{Frame\ m} = TS_m/T_{Frame}}$).
  - For each $\mathbf{TS_m}$, BS_N informs all $\{\mathbf{id^{(1)}_{k,m}}\}$ about $\mathbf{P^{min,\ (1)}_{\ m}}$ and $\mathbf{P^{max,\ (1)}_{\ m}}$ where $\mathbf{P^{min,\ (1)}_{\ m}}$ is the minimal payoff from $\{\mathbf{id^{(1)}_{k,m}}\}_{selected}$ and $\mathbf{P^{max,\ (1)}_{\ m}}$ is the maximal payoff from $\{\mathbf{id^{(1)}_{k,m}}\}_{selected}$ during the first iteration. With this approach, each BS_k is directly informed whether it has been selected or not, and has some information on how far it is from $\mathbf{P^{min,\ (1)}_{\ m}}$ while still having some information on $\mathbf{P^{max,\ (1)}_{\ m}}$. This approach enables to keep the privacy of competing $\{\mathbf{id^{(1)}_{k,m}}\}$ on $\mathbf{TS_m}$.

n^th^ iteration of the credit tokens based bidding phase

This phase is composed of 2 sequences as follows:

- In sequence (6):
  - If $\mathbf{P^{(1)}_k < P^{min,\ (1)}_{\ m}}$, this means that BS_k has not been selected for being granted the resources he has bided for during the first iteration n = 1. More generally speaking, for n>1, if $\mathbf{P^{(n-1)}_k < P^{min,\ (n-1)}_{\ m}}$, this means that BS_k has not been selected for being granted the resources he has bided for during the $(n-1)^{th}$ iteration.
  - If $\mathbf{P^{(n-1)}_k < P^{min,\ (n-1)}_{\ m}}$ and if BS_k is still interest to be allocated with the additional resources he initially requested for, it can propose a new $\mathbf{BS\_CT^{(n)}_k}$ for the n^{th} iteration. Then, BS_k computes the new $\mathbf{P^{(n)}_k = BS\_CT^{(n)}_k * x_k * T_{Renting} * N_{Frame\ m}}$ where $\mathbf{x_k}$,$\mathbf{T_{Renting}}$ and $\mathbf{N_{Frame\ m}}$ are fixed for all n on $\mathbf{TS_m}$.
  - If $\mathbf{P^{(n)}_k > P^{(n-1)}_k}$ and $\mathbf{P^{(n)}_k > P^{min,\ (n-1)}_{\ m}}$, BS_k expresses its interest to keep on participating in the bidding with the new bid $\mathbf{P^{(n)}_k}$. In that case, it informs BS_N with its new (update) value of $\mathbf{BS\_CT^{(n)}_k}$. In case $\mathbf{P^{(n)}_k = P^{(n-1)}_k}$ or $\mathbf{P^{(n)}_k < P^{min,\ (n-1)}_{\ m}}$, BS_k leaves the bidding phase and will not be granted with the additional resources he asked for.
- In sequence (7), BS_N updates $\{\mathbf{id^{(n-1)}_{k,m}}\}$ into $\{\mathbf{id^{(n)}_{k,m}}\}$. Based on the new received biddings $\{\mathbf{BS\_CT^{(n)}_k}\}$ for each $\mathbf{TS_m}$, the master BS_N calculates the new payoff $\mathbf{P^{(n)}_k = BS\_CT^{(n)}_k * x_k * T_{Renting} * N_{Frame\ m}}$ for each bidder k who still participates to the bidding. Then, for each $\mathbf{TS_m}$, BS_N searches the subset $(\{\mathbf{id^{(n)}_{k,m}}\}_{selected})$ of $\{\mathbf{id^{(n)}_{k,m}}\}$ such as sum($\mathbf{x_k}$) = **1** and sum($\mathbf{P^{(n)}_k}$) is maximal. Next, BS_N performs the same actions as in sequence (5): for each $\mathbf{TS_m}$, BS_N informs all $\{\mathbf{id^{(n)}_{k,m}}\}$ about $\mathbf{P^{min,\ (n)}_{\ m}}$ and $\mathbf{P^{max,\ (n)}_{\ m}}$ where $\mathbf{P^{min,\ (n)}_{\ m}}$ is the minimal payoff from $\{\mathbf{id^{(n)}_{k,m}}\}_{selected}$ and $\mathbf{P^{max,\ (n)}_{\ m}}$ is the maximal payoff from $\{\mathbf{id^{(n)}_{k,m}}\}_{selected}$ during the n^{th} iteration.

Final pricing and credit tokens transaction phase
This phase is composed of two sequences as follows:

- In sequence (8):
  - As long as $\mathbf{T_{End\ Bidding}}$ - $\mathbf{T_{Start\ Bidding}}$>0 (i.e. the bidding phase duration has not yet elapsed), n is increased and the credit tokens based bidding phase mechanisms of the previous paragraph "***n^{th} iteration of the credit tokens based bidding phase***" are applied.
  - When $\mathbf{T_{End\ Bidding}}$ - $\mathbf{T_{Start\ Bidding}}$ = 0, bidding phase is over. None BS_k can propose a new bid. $\{\mathbf{id^{(n\ final)}_{k,m}}\}_{selected}$ is derived. At this point, BS_N derives the clearing price auction $\mathbf{BS\_CPA_k}$ (expressed as a number of credit tokens per time unit) for each $\mathbf{TS_m}$ and each k from $\{\mathbf{id^{(n\ final)}_{k,m}}\}$. For each k and m, $\mathbf{BS\_CPA_k}$ can correspond to the $\mathbf{BS\_CT^{(final)}_k}$, or for example can follow another price auction method.
- In sequence (9), each BS_k is requested to pay $\mathbf{Pr_k = BS\_CPA_k * x_k * T_{Renting} * N_{Frame\ m}}$ to be allowed to use the resources it won on its corresponding $\mathbf{TS_m}$. Provided that $\mathbf{Pr_k}$ does not exceed the credit tokens account of BS_k, the token transaction between BS_N and each BS_k is performed.

Credit tokens based bandwidth granting phase
This phase is composed of the single sequence (10). During this phase, BS_N grants the resource to each BS_k who has successfully performed the credit transaction operation in sequence (9).

Resource usage phase
After BS_k has been granted with the resources, BS_k can use them during during $\boldsymbol{x_k * T_{Renting}}$ time unit of NW_N and for $\mathbf{N_{Frame\ m}}$ frames from the beginning on its corresponding $\mathbf{TS_m}$.

4 Proposed text changes

4.1 In Introduction paragraph of section 15.7.2.2.6

During session #38, it has been agreed that only the text related to the mechanisms of case (1) has to be included in [2]. However, some text related to the mechanisms of case (2) remains in [2]. In this paragraph, the proposed text change intends to remove the text related to case (2) in the introduction paragraph of section 15.7.2.2.6. This proposed text change is highlighted with the word revision marks as follows:

"Spectrum sharing between several networks (NW) can be achieved through the sharing of a common MAC frame [2] between the different NWs as exampled by Figure h33. In such a MAC frame structure, dedicated portions (denoted as "master NW sub-frames") of the frame are periodically and exclusively allocated to a NW (denoted as the "master NW") respectively in the forward and reverse link. The terminology used hereafter defines a slave NW as a NW that may operate during the other master NWs sub-frames. With respect to this definition, the slave NW sub-frames are the time intervals operating in parallel of the master NWs sub-frames.

Additional flexibility can be provided by such a frame structure if~~: (1)~~ the length of each master sub-frame (interference free sub-frame) can be dynamically adjusted as a function of the spatial and temporal traffic load variations of each NW as stated in section 15.2.1.1.1 of [2]. ~~; (2) the slave NWs sub-frames can be allocated with the same sub-carriers (co-channel) as the master NW during the master NW sub-frames transmissions.~~

~~*Requirements (2) can be envisaged if provided that the master NW perceives a co-channel interference level lower than an admissible interference threshold explicitly agreed with the slave NWs to ensure master NW's QoS (QoS*~~$_{Master}$~~*) is guaranteed. Similarly, parallel transmissions can be envisaged if the slave NWs can negotiate with master NW to be provided with a guaranteed QoS (QoS*~~$_{Slave}$~~*) and if contention issues between slave NWs are resolved.*~~

~~*Given requirements (1) and (2),*~~*To achieve this, this section*~~*contribution*~~ *proposes the dynamic coordination of the frame structure sharing between BSs when several master* ~~*and slave*~~ *NWs compete to share this common shared MAC frame."*

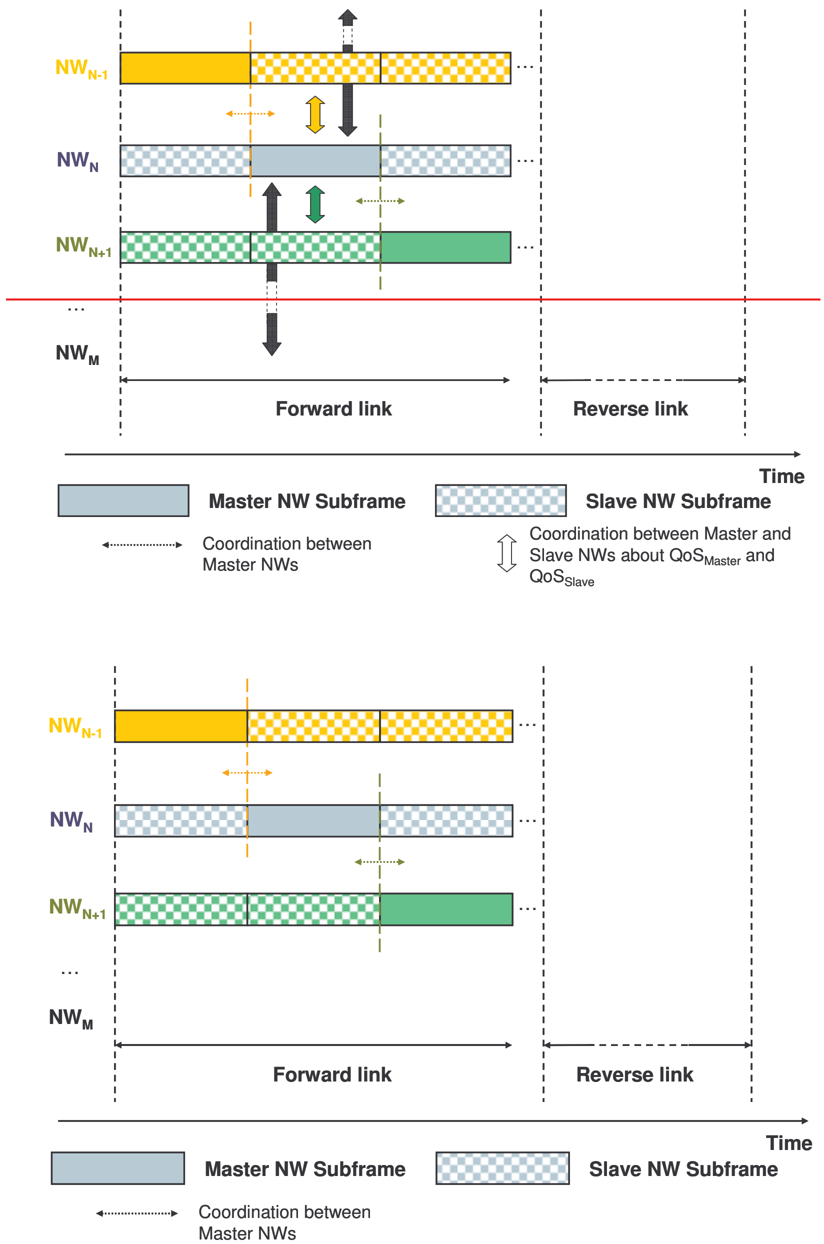

Figure h33: **Example of TDD based MAC frame sharing structure between M NWs**

4.2 In section 15.7.2.2.6.1

During session #38, it has been agreed that only the text related to the mechanisms of case (1) has to be included in [2]. However, some text related to the mechanisms of case (2) remains in [2]. In this paragraph, the proposed text change intends to remove the text related to case (2) in section 15.7.2.2.6.1. This proposed text change is highlighted with the word revision marks as follows:

"In order to solve contention access channel and resources scheduling issues between NWs, ~~T~~the first step consists in defining credit tokens and designing appropriate reserve price auctioning and bidding mechanisms. ~~to solve contention access channel issues between NWs~~. Then, on the basis of the credit tokens based mechanisms usage, the second step consists in managing dynamically (temporally) the bandwidth ~~(in time and frequency)~~ requests and grants mechanisms for the sharing of the master sub frames within the common MAC frame.~~of the common shared MAC frame between BSs of master and slave NWs competing for spectrum sharing.~~

Based on the credit tokens transactions (selling, purchase and awarding), these two steps provide the mechanisms to enable spectrum efficiency and a fair spectrum usage in a real time fashion, while ensuring both the master and slave NWs QoS. These two steps enable to manage spectrum sharing between master NWs themselves.~~, and also between master and slave NWs.~~ The result is the dynamic shaping of the MAC frame structure sharing as a function of the space time traffic intensity variations ~~, admissible co-channel interference,~~ and the dynamic credit tokens portfolio account of ~~both~~ the master ~~and slave~~ NWs. The transaction mechanisms are detailed in the following sections."

4.3 In section 15.7.2.2.6.2

During session #38, it has been agreed that only the text related to the mechanisms of case (1) has to be included in [2]. However, some text related to the mechanisms of case (2) remains in [2]. In this paragraph, the proposed text change intends to remove the text related to case (2) in section 15.7.2.2.6.2. This proposed text change is highlighted with the word revision marks as follows:

"

- *Each NW is initially allocated with a given credit tokens account.*
- *Negotiation for spectrum sharing between NWs is based on credit tokens transactions.*
- *Credit tokens transactions occur dynamically between a seller (master NW owner of the radio resources during the active master sub-frame) and one or several bidders (the other master NWs ~~or slave NWs~~).*
- *The negotiation occurs dynamically ~~either:~~*
- *~~B~~between master NWs ~~(denoted "Case 1" in the following)~~ to agree the length of each master sub-frame as a function of the spatial and temporal traffic load variations need of each master NW. ~~(refers to above requirement (1) of section 2)~~.*
- *~~Between master and slave NWs (denoted "Case 2" in the following) to select the slave NWs allowed operating in parallel of the master sub-frame based on QoS_{Slave} and QoS_{Master} (refers to above requirement (2) of section 2).~~*

"

4.4 In section 15.7.2.2.6.3

Text of section 3 of this document is intended to update/upgrade the existing text within the section 15.7.2.2.6.3.

5 Conclusion

The topic addressed by this contribution is related to the cooperative based co-existence resolution and negotiation protocol. Firstly, this contribution has proposed enhanced mechanisms enabling a more flexible and scalable credit tokens based distributed scheduling of the master sub frames between cooperative BSs. The new proposed mechanism is compatible with the initial one, and enhances the initial one by proposing a multi stages (iterative) mechanism. Secondly, this contribution has proposed some text changes for the section 15.7.2.2.6 of [2]. The proposed mechanisms are applicable to facilitate the co-existence among license exempt based 802.16 systems in a fair fashion, but they are also applicable to the co-existence of license exempt based 802.16 systems with primary systems like IEEE 802.11. These mechanisms have been presented in the case of a specific repetitive pattern (i.e. for a given MAC sub-frame structure type), but are also applicable to any type of the repetitive patterns of section 15.2.1.1.1 in [2]. Finally, the proposed principles are also applicable to the following phases of the "community entry of new BS" phase: (i) selection of an interference free master sub-frame, and (ii) creation of a new master sub-frame by a new BS.

References

[1] IEEE C802.16h-05/020r1 – Proposal for credit tokens based co-existence resolution and negotiation protocol, 2005-07-11

[2] IEEE 802.16h-05/022 - pre- draft Working Document for P802.16h, 2005-09-28