Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Text remedies for credit token based co-existence protocol section**
Date Submitted	**2006-07-10**
Source(s)	David Grandblaise Motorola Labs Parc Les Algorithmes Commune de Saint Aubin 91193 Gif sur Yvette, France Voice: +33 (0)1 6935 2582 Fax: +33 (0)1 6935 4801 mailto: david.grandblaise@motorola.com
Re:	Recirculation of Working Group Review of Working Document 80216h-06_015
Abstract	This contribution provides remedies to comment #3 of the session #43's Working Group Review. The text remedies for credit token based co-existence protocol are proposed for section 15.6.2.2.6 of the working document [1].
Purpose	Text remedies to comment #3 of the session #43's Working Group Review.
Notice	
Release	
Patent Policy and Procedures	

Text remedies for credit tokens based rental protocol section

David Grandblaise
Motorola

Overview

This contribution suggests remedies to action items from session #43's Working Group Review, namely Comment 3 of [2] – Correction of terminology in the credit token based rental protocol section. The text changes are intended to be included in the section 15.6.2.2.6 of the working document [1].

Specific editorial changes

This section provides a list of changes to the draft document.

Blue text represents specific editorial additions.

~~Red strikethrough~~ text is to be deleted.

Black text is text already in the draft.

Bold italic text is editorial instructions to the editor.

Text proposal for section 15.6.2.2.6

Add the text below to update section 15.6.2.2.6

15.6.2.2.6 Negotiation between master systems (SYSs)~~NWs~~

Spectrum sharing between several systems (SYS) ~~networks (NW)~~ can be achieved through the sharing of a common MAC frame between the different SYSs~~NWs~~ as exampled by Figure h44. In such a MAC frame structure, dedicated portions (denoted as "master SYS~~NW~~ sub-frames") of the frame are periodically and exclusively allocated to a SYS~~NW~~ (denoted as the "master SYS~~NW~~") respectively in the forward and reverse link. The terminology used hereafter defines a slave SYS~~NW~~ as a SYS~~NW~~ that may operate during the other master SYS ~~NWs~~ sub-frames. With respect to this definition, the slave SYS~~NW~~ sub-frames are the time intervals operating in parallel of the master SYS~~NWs~~ sub-frames.

Additional flexibility can be provided by such a frame structure if 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 SYS~~NW~~ as stated in section 15.2.1.1.1.

To achieve this, this section proposes the dynamic coordination of the frame structure sharing between BSs when several master -SYSs~~NWs~~ compete to share this common shared MAC frame.

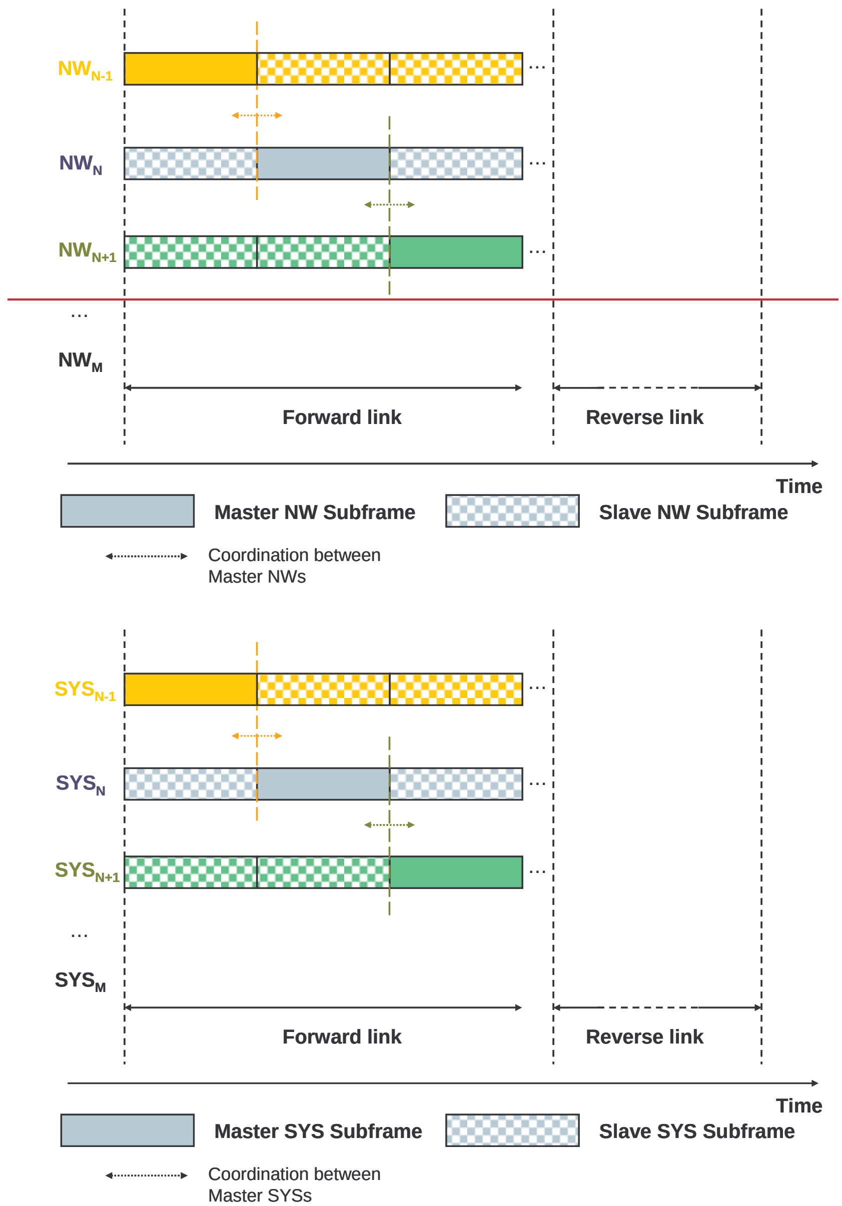

Figure h44: **Example of TDD based MAC frame sharing structure between M SYSs~~NWs~~**

15.6.2.2.6.1 General principle

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

Based on the credit tokens transactions (~~selling~~assignment, ~~purchase~~release 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 SYSs~~NWs~~ QoS. These two steps enable to manage spectrum sharing between master SYSs~~NWs~~ themselves. The result is the dynamic shaping of the MAC frame structure sharing as a function of the space time traffic intensity variations and the dynamic credit tokens portfolio account of the master SYSsNWs. The transaction mechanisms are detailed in the following sections.

15.6.2.2.6.2 Credit tokens assignment and usage principles

- Each SYSNW is initially allocated with a given credit tokens accountbudget.
- Negotiation for spectrum sharing between SYSsNWs is based on credit tokens transactions.
- Credit tokens transactions occur dynamically between a credit tokens sellerofferor (master SYSNW owner of the radio resources during the active master sub-frame) and one or several credit tokens biddersrequesters (the other master SYSsNWs).
- The negotiation occurs dynamically between master SYSsNWs to agree the length of each master sub-frame as a function of the spatial and temporal traffic load variations need of each master SYSNW.

15.6.2.2.6.3 Negotiation between master SYSsNWs

15.6.2.2.6.3.1 Definition and notation

- BS_N denotes the BS belonging to the master NWSYS_N.
- BS_k denotes the BS belonging to the slave NWSYS_k.
- Each BS_k can dynamically makepropose a bidnumber of credit tokens $\mathbf{BS\_CT^{(n)}_k}$ at the n^{th} iteration. This bidproposal corresponds to the amountnumber of credit tokens per time unit corresponding to the BS_k during the n^{th} iteration of the auctioning/biddingnegotiation phase.
- Resource scheduling is carried out by an auction likeinspired mechanism. The auctionnegotiation type used for the scheduling is dynamic in time. Starting from the reserved price auction **RPA** minimum number of credit tokens required (**MRCTN**) by the master BS to its share radio resources, the price of auctionthe number -of credit tokens is successfullyiteratively raisedincreased (at each iteration n) until the winning bidders requesters remain.

15.6.2.2.6.3.2 Dynamic credit tokens based scheduling cycle

The contribution proposes aThe dynamic scheduling cycle aims at coordinating between one BS_N of master NWSYS_N and several BS_k of different slave NWSYS_k. For the sake of simplicity, the cycle is illustrated (Figure h 45 and Figure h 46) for one BS_N and one BS_k of a given slave NWSYS_k. The cycle is composed of different phases, and each phase can be composed of several sequences as follows.

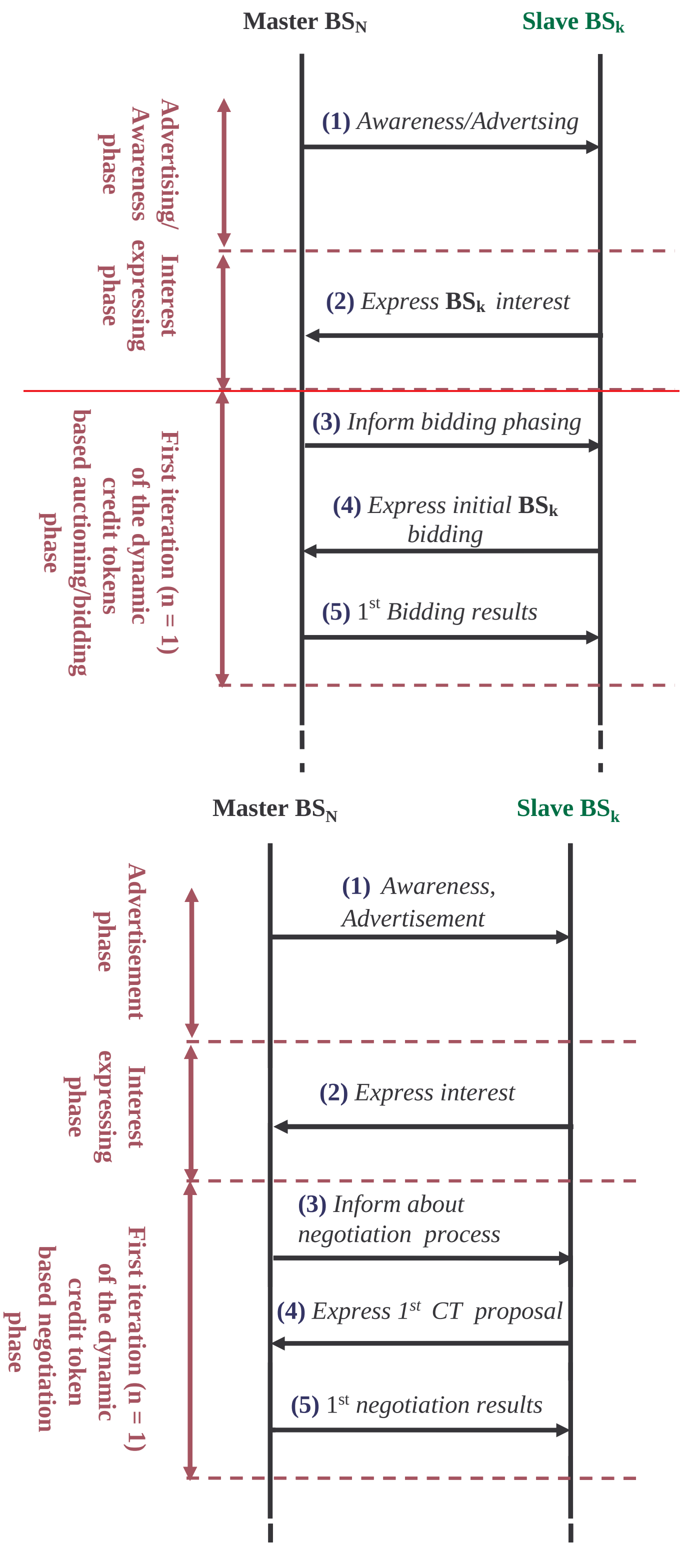

Figure 45: **Dynamic (iterative) credit tokens based scheduling cycle – (sequences (1) to (5))**

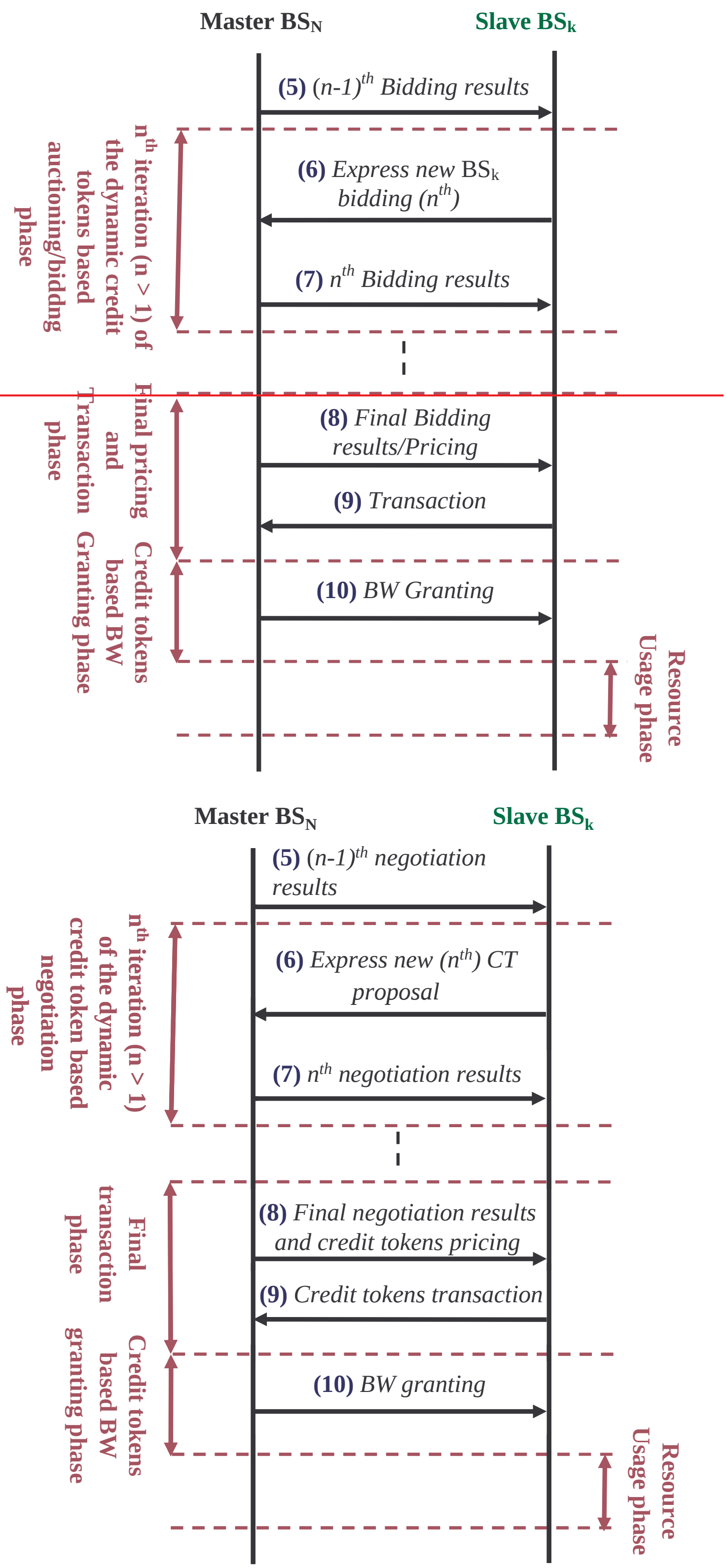

Figure 46: **Dynamic (iterative) credit tokens based scheduling cycle – (sequences (5) to (10))**

15.6.2.2.6.3.3 Negotiation mechanisms between master SYSs~~NWs~~

For each of the phase of the credit tokens based scheduling cycle presented in section 15.6.2.2.6.3.2, this section 15.6.2.2.6.3.3 describes the details of the enhanced mechanisms.

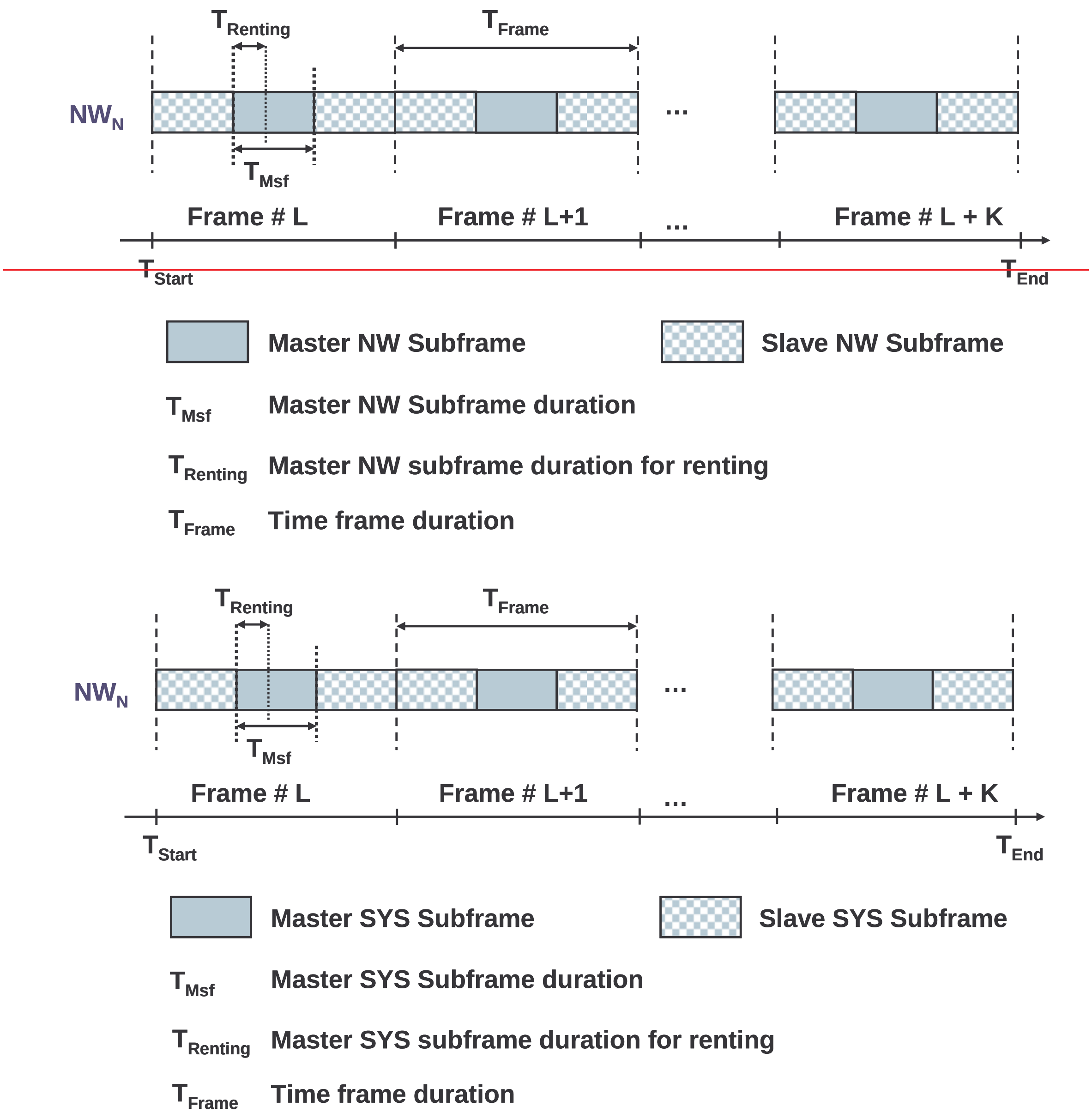

Figure h47: **Simplified MAC frame structure illustrating master SYS~~NW~~ sub-frame renting principle and associated notations**

Advertising/Awareness phase

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

- The master ~~NW~~SYS_N (~~seller~~offeror) advertises that its periodic assigned master sub-frame is open for renting (Figure h47) 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~~SYS_N proposes a ~~reserve price auction **RPA**~~ minimum number of credit tokens required (**MRCTN**) for this renting. The ~~**RPA**~~**MRCTN** 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~~negotiation. If the BS_k is interested, it communicates its $\mathbf{id_k}$ to the master BS_N.

First iteration (n = 1) of the dynamic credit tokens based ~~auctioning/bidding~~negotiation 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~~negotiation:
  - $\mathbf{T_{Start\ \sout{Bidding}Negotiation}}$: time from which the ~~bidding~~negotiation phase will start,
  - $\mathbf{T_{End\ \sout{Bidding}Negotiation}}$: time at which the ~~bidding~~negotiation phase will end ($\mathbf{T_{End\ \sout{Bidding}Negotiation}} < \mathbf{T_{Start}}$),

  <u>Note</u>: 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: ~~**BID**~~$\mathbf{CTP^{(1)}_k = \{BS\_CT^{(1)}_k, x_k, T_{Start\ k}, T_{End\ k}\}}$ where:
  - $\mathbf{CTP^{(1)}_k}$ is the credit tokens proposal vector of BS_k at the first (n = 1) iteration of the negotiation with the master BS_N. $\mathbf{CTP^{(1)}_k}$ is composed of $\mathbf{BS\_CT^{(1)}_k, x_k, T_{Start\ k}}$ and $\mathbf{T_{End\ k}}$.
  - $\mathbf{BS\_CT^{(1)}_k}$ is the ~~amount~~number 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~~requesters $\{\mathbf{id^{(1)}_k}\}$, 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~~requesters $\{\mathbf{id^{(1)}_k}\}$ 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~~requester $\mathbf{id^{(1)}_{k,m}}$ competes with his respective ~~**BID**~~$\mathbf{CTP^{(1)}_k}$.
  - 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~~requester k, and searches the subset $(\{\mathbf{id^{(1)}_{k,m}}\}_{selected})$ of $\{\mathbf{id^{(1)}_{k,m}}\}$ such as $\text{sum}(\mathbf{x_k}) = \mathbf{1}$ and $\text{sum}(\mathbf{P^{(1)}_k})$ 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 dynamic credit tokens based ~~auctioning/bidding~~negotiation phase

This phase is composed of 2 sequences as follows:

- In sequence (6):
  - If $\mathbf{P^{(1)}_k} < \mathbf{P^{min,\,(1)}_m}$, this means that BS_k has not been selected for being granted the resources he has ~~bided~~requested for during the first iteration n = 1. More generally speaking, for n>1, if $\mathbf{P^{(n-1)}_k} < \mathbf{P^{min,\,(n-1)}_m}$, this means that BS_k has not been selected for being granted the resources he has ~~bided~~requested for during the $(n-1)^{th}$ iteration.
  - If $\mathbf{P^{(n-1)}_k} < \mathbf{P^{min,\,(n-1)}_m}$ 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 $\mathbf{P^{(n)}_k} = \mathbf{BS\_CT^{(n)}_k * x_k * T_{Renting} * N_{Frame\ m}}$ where $\mathbf{x_k}$, $\mathbf{T_{Renting}}$ and $\mathbf{N_{Frame\ m}}$ are fixed for all n on $\mathbf{TS_m}$.
  - If $\mathbf{P^{(n)}_k} > \mathbf{P^{(n-1)}_k}$ and $\mathbf{P^{(n)}_k} > \mathbf{P^{min,\,(n-1)}_m}$, BS_k expresses its interest to keep on participating in the ~~bidding~~negotiation with the new proposal~~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 $\mathbf{P^{(n)}_k} = \mathbf{P^{(n-1)}_k}$ or $\mathbf{P^{(n)}_k} < \mathbf{P^{min,\,(n-1)}_m}$, BS_k leaves the ~~bidding~~negotiation 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~~proposals $\{\mathbf{BS\_CT^{(n)}_k}\}$ for each $\mathbf{TS_m}$, the master BS_N calculates the new payoff $\mathbf{P^{(n)}_k} = \mathbf{BS\_CT^{(n)}_k * x_k * T_{Renting} * N_{Frame\ m}}$ for each ~~bidder~~requester k who still participates to the ~~bidding~~negotiation. 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 $sum(\mathbf{x_k}) = \mathbf{1}$ 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~~ Final negotiation results and credit tokens pricing

This phase is composed of two sequences as follows:

- In sequence (8):
  - As long as ~~$\mathbf{T_{End\ Bidding}}$ –~~ $\mathbf{T_{Start}}$ ~~Bidding~~Negotiation has not been reached~~> 0~~ (i.e. the ~~bidding~~negotiation phase duration has not yet elapsed), n is increased and the credit tokens based ~~bidding~~negotiation phase mechanisms of the previous paragraph "***n^{th} iteration of the dynamic credit tokens based ~~auctioning/bidding~~negotiation phase***" are applied.
  - When ~~$\mathbf{T_{End\ Bidding}}$ –~~ $\mathbf{T_{Start}}$ ~~Bidding~~Negotiation has been reached~~= 0~~, ~~bidding~~negotiation phase is over. None BS_k can propose a new ~~bid~~credit tokens proposal. $\{\mathbf{id^{(n\ final)}_{k,m}}\}_{selected}$ is derived. At this point, BS_N derives the final credit tokens price~~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~~ derivation method.
- In sequence (9), each BS_k is requested to provide~~pay~~ $\mathbf{Pr_k} = \mathbf{BS\_CPA_k * x_k * T_{Renting} * N_{Frame\ m}}$ credit tokens to BS_N to be allowed to use the resources it has been assigned~~won~~ after the negotiation on its corresponding $\mathbf{TS_m}$. Provided that $\mathbf{Pr_k}$ does not exceed the credit tokens ~~account~~budget of BS_k, the credit tokens 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 $x_k * T_{Renting}$ time unit of ~~NW~~SYS$_N$ and for $N_{Frame\ m}$ frames from the beginning on its corresponding TS_m.

References

[1] IEEE 802.16h-06/015: Part 16: Air Interface for Fixed Broadband Wireless Access Systems Amendment for Improved Coexistence Mechanisms for License-Exempt Operation, Working document; 2006-05-31

[2] 80216h-06_012r1: Working Group Review Commentary file from session #43.