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Title	Proposal for MAC frame mechanisms supporting enhanced credit tokens based co-existence resolution and negotiation protocol
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Re:	Call for Contributions, IEEE 802.16h Task Group on License-Exempt Coexistence, IEEE 80216h-05/014
Abstract	MAC frames mechanisms enabling an over the air distributed implementation of the different phases of the enhanced credit tokens based co-existence resolution and negotiation protocol
Purpose	Provide flexible mechanisms for a fair and efficient sharing of the common MAC frame
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Proposal for MAC frame mechanisms supporting enhanced credit tokens based co-existence resolution and negotiation protocol

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1 Introduction

In a previous contribution [1], credit tokens based scheduling mechanisms for a cooperative based co-existence resolution and negotiation protocol have been proposed to support negotiation of the master nominal sub frames (interference free sub frames) length between master BSs. These mechanisms have been included within the section 15.7.2.2.6 of the IEEE 802.16h draft document [2]. In order to provide additional flexibility and scalability to this initial mechanism, an enhanced version (dynamic (iterative) based) of this mechanism has been proposed in [3]. Purpose of this new contribution is to provide the MAC frame mechanisms enabling the over the air implementation of the different phases of the algorithm presented in [3]. The text of this new contribution is intended for inclusion in a new subsection within the section 15.7.2.2.6 of the IEEE 802.16h draft document [2].

2 Background

[3] has proposed: (1) a real time and dynamic (iterative) credit tokens based scheduling cycle enabling the inter BS spectrum sharing in a distributed fashion; (2) the algorithm related to the different phases of the dynamic (iterative) credit tokens based scheduling cycle. For the sake of simplicity, the proposed cycle in [3] 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 is composed of several sequences. This new contribution provides the mechanisms for the UL and DL management of the MAC frame enabling the implementation of the algorithm for the different sequences. This new contribution uses as background the algorithm related to the different phase of the scheduling cycle. This new contribution refers to this algorithm proposed in [3].

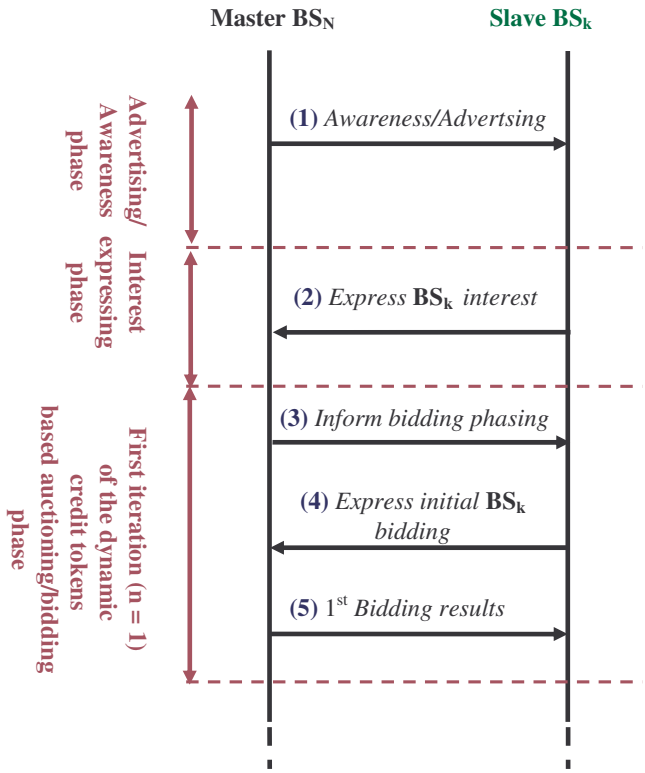

Figure 1: **Dynamic (iterative) credit tokens based scheduling cycle – (sequences (1) to (5))**

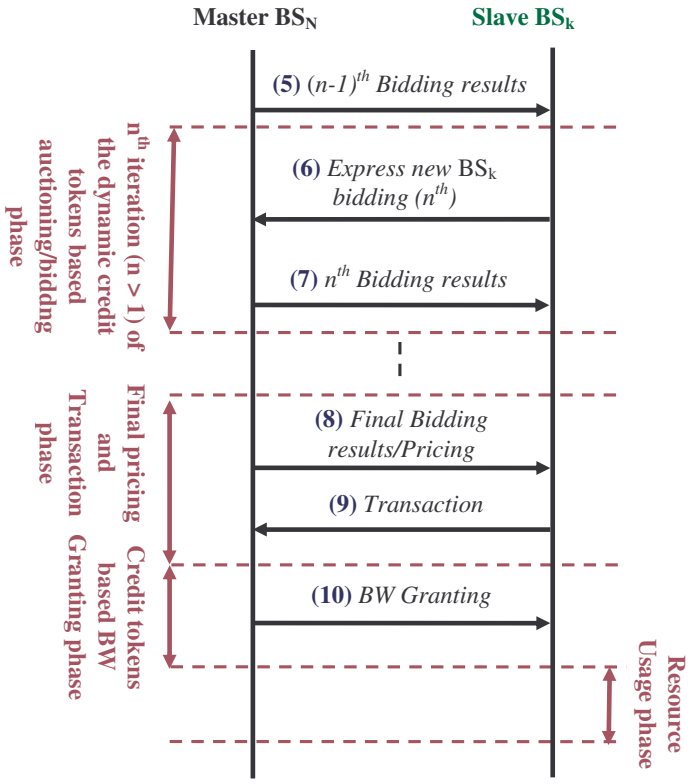

Figure 2: **Dynamic (iterative) credit tokens based scheduling cycle – (sequences (5) to (10))**

3 Proposed mechanisms

Text of section 3 is intended for inclusion in a new subsection within the section 15.7.2.2.6. of [2].

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.

3.2 Overall MAC frame structure supporting the dynamic scheduling cycle

The implementation of different phases of the dynamic scheduling cycle requires the introduction of management mechanisms into the MAC frame structure. The contribution proposes the following overall MAC frame structure (Figure 3) supporting all phases of the cycle. This MAC frame is structured as follows (for the sake of simplicity, the illustration only considers 3 BSs: one BS (BS_N) for the master NW, one BS (BS_k) for slave NW_k and one BS [BS_j] for slave NW_j):

- Each MAC frame is divided into the DL and UL sub frame,
- A dedicated MAC DL management sub frame (respectively a dedicated MAC UL management sub frame) is used for the management of the DL sub frame (respectively used for the management of the UL sub frame),
- The content of the MAC DL and UL management sub frames is structured to support the communications between the master BS_N and any of the slave BS_k during the different involved phases of the cycle.

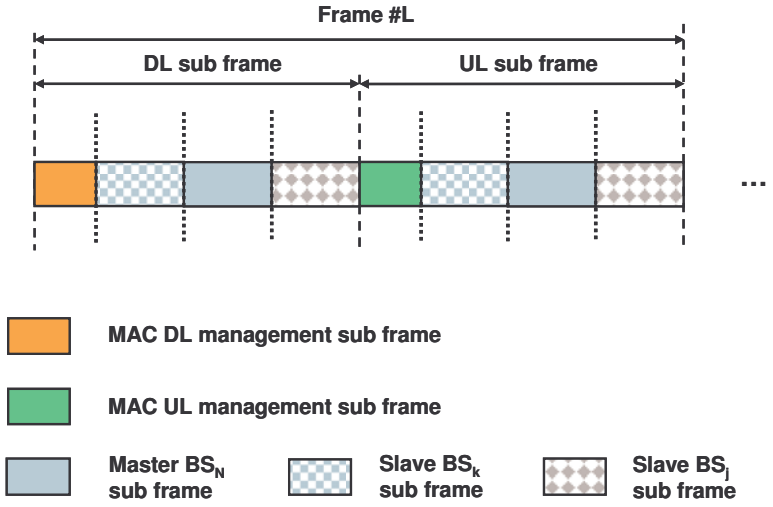

Figure 3: **Overall MAC frame structure supporting the dynamic scheduling cycle**

Note: The position and the duration of the MAC management sub frames:

- Can either be set for each frame and priory agreed between all NWs from the beginning (static approach),

- Or they can be periodically adapted between the NWs as function of time depending on the needs (dynamic approach). This could be achieved, for example, by wired information exchange between local BS databases via IP communication (via a server) between the involved NWs.

The MAC DL management sub frame (Figure 4) is divided into two sub frames as follows:

- A broadcasting and a multicasting sub frame,
- Each is also divided into sub frames. Each sub frame is dedicated to one BS,
- The broadcasting sub frame is reserved for the "advertising/awareness" phase (sequence (1)),
- The multicasting sub frame is reserved for:
  - the "first iteration (n = 1) of the credit tokens based auctioning/bidding" phase (sequences (3) and (5)),
  - the "n^{th} iteration (n > 1) of the dynamic credit tokens based auctioning/bidding" phase (sequences (7)), and
  - the "Final pricing and Transaction" phase (sequence (8)).

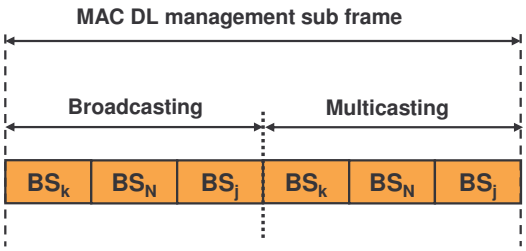

Figure 4: **MAC DL management sub frame**

The MAC UL management sub frame (Figure 5) is divided into two sub frames as follows:

- A contention and a data transmission sub frame,
- Each is also divided into sub frames. Each sub frame is dedicated to one BS,
- The contention sub frame is reserved for the "Interest expressing phase" (sequence (2)),
- The data transmission sub frame is reserved for:
  - the "first iteration (n = 1) of the credit tokens based auctioning/bidding" phase (sequences (4)),
  - the "n^{th} iteration (n > 1) of the dynamic credit tokens based auctioning/bidding" phase (sequences (6)), and
  - the "Final pricing and Transaction" phase (sequences (9)).

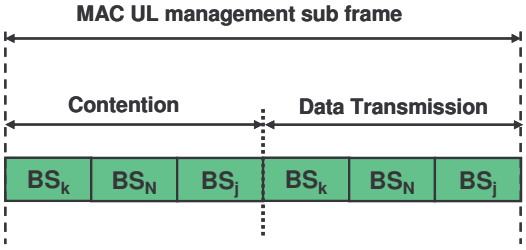

Figure 5: **MAC UL management sub frame**

The details of the mechanisms on the broadcasting, multicasting, contention and data transmission sub frames are in section 3.3.

Note: The organisation (in term of position, duration) of the broadcasting, multicasting, contention and data transmissions phases:

- Can either be set fixed for each frame and priory agreed between all NWs from the beginning (static approach),
- Or they can be periodically adapted between the NWs as function of time depending on the needs (dynamic approach). This could be achieved, for example, by wired information exchange between local BS databases via IP communication (via a server) between the involved NWs.

3.3 MAC frame mechanisms supporting the dynamic scheduling cycle

Based on the overall MAC frame structure presented in section 3.2, this section details the mechanisms used by the MAC frame to support the different sequences of the algorithm. For each sequence, details of the algorithm can be found in [3].

Advertising/Awareness phase

In sequence (1), the master BS_N broadcasts via an over the air broadcast channel the following information to the surrounding BS_ks: $\mathbf{T_{Start}}$, $\mathbf{T_{End}}$, $\mathbf{T_{Start\ Renting}}$, $\mathbf{T_{End\ Renting}}$, **RPA.**

The MAC frame mechanisms enabling these operations can be implemented in the MAC DL Management sub frame as follows (Figure 6):

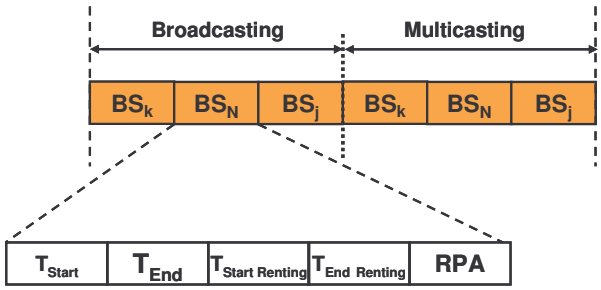

Figure 6: **MAC frame format - Sequence (1)**

Interest expressing phase

The MAC frame mechanisms enabling sequence (2) can be implemented in the MAC UL Management sub frame by using the contention sub frame (contention mini slots). The contention mechanism (Figure 7) to be used can be the Slotted Aloha protocol (jointly with a collision resolution algorithm like a binary exponential backoff) but with the following adaptation: once a slave BS_k has managed to send its $\mathbf{id_k}$ information (i.e. it received successful acknowledgement from BS_N), its remains silence to let the others interested BS_k to transmit their $\mathbf{id_k}$.

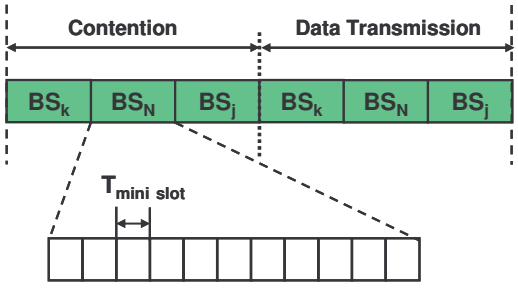

Figure 7: **MAC frame format - Sequence (2)**

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 sends 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 ($\mathbf{T_{End\ Bidding} < T_{Start}}$),
  - **DCD, DL-MAP** for the management of the multicasting sub frame of the MAC DL management field,
  - **UCD, UL-MAP** for the management of the data transmission sub frame of the MAC UL management field.

  The MAC frame mechanisms enabling these operations can be implemented in the multicasting sub frame of the MAC DL management field as follows (Figure 8):

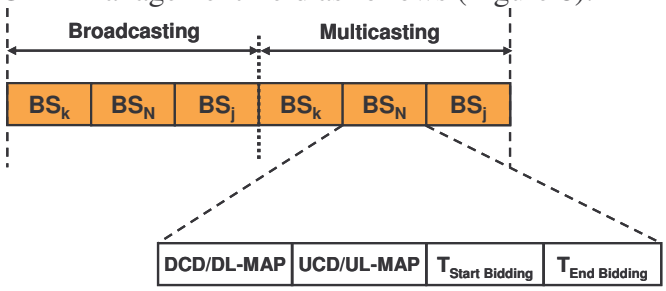

Figure 8: **MAC frame format - Sequence (3)**

- Sequence (4): for this first iteration, the MAC frame mechanisms enabling the transmission of sequence (4) information can be implemented as follows:
  - In the multicasting sub frame of the MAC DL management field (Figure 8), the UCD, UL-MAP provides the information to each BS_k from $\{\mathbf{id}^{(1)}_k\}$ at which moment each BS_k will be able to transmit its $\mathbf{BID}^{(1)}_k$ in the data transmission field of the MAC UL management field.

Note: For this first iteration, $\mathbf{BS\_CT}^{(1)}_k$ is expressed in absolute value.

  - The data transmission field of the MAC UL management field is organised as follows (Figure 9):

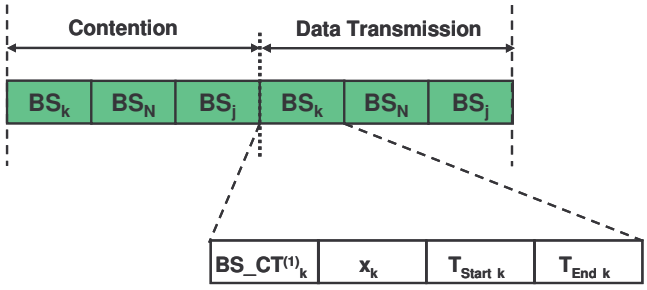

Figure 9: **MAC frame format - Sequence (4)**

- The MAC frame mechanisms enabling the transmission of the information of sequence (5) can be implemented as follows (Figure 10):

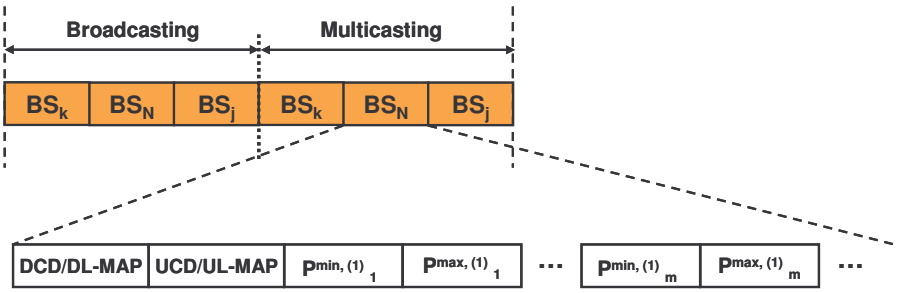

Figure 10: **MAC frame format - Sequence (5)**

In particular, the DCD/DL-MAP provides the necessary information when each $\mathbf{id}^{(1)}_{k,m}$ has to listen to the multicasting sub frame (Figure 10) so that each $\mathbf{id}^{(1)}_{k,m}$ only listens to the part dedicated to it (i.e. related to its $\mathbf{TS}_m$).

n^{th} iteration of the credit tokens based auctioning/bidding phase

This phase is composed of 2 sequences as follows:

- The MAC frame mechanisms enabling the transmission of the information $\mathbf{BS\_CT}^{(n)}_k$ in sequence (6) can be implemented as follows:
  - For each $\mathbf{TS}_m$, each BS_k who has expressed the need to send its $\mathbf{BS\_CT}^{(n)}_k$, enters into a reservation phase in the contention sub frame of the MAC UL management field. This contention sub frame (Figure 11) enables the BS_k to communicate its $\mathbf{id}_k$ to the BS_N. This is achieved by using contention mini slots (slotted Aloha protocol jointly with a collision resolution algorithm like a binary exponential backoff) but with the following adaptation: once a slave BS_k has managed to send its $\mathbf{id}_k$ information (i.e. it received successful acknowledgement from BS_N), its remains silence to let the others interested BS_k to transmit their $\mathbf{id}_k$.

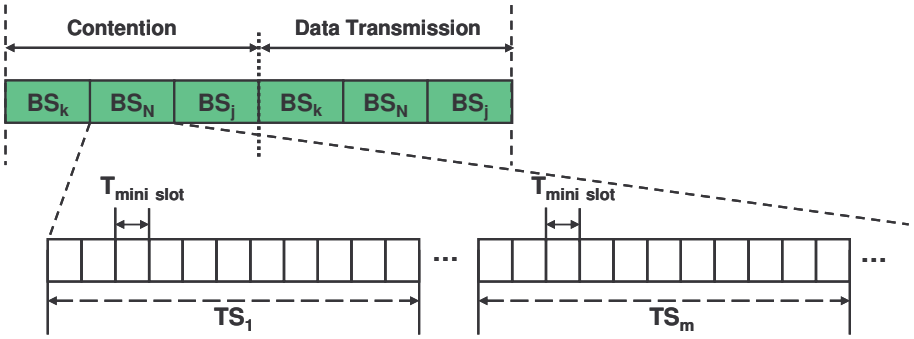

Figure 11: **MAC frame format - Sequence (6) - contention**

  - For each $\mathbf{TS}_m$, based on the received $\{\mathbf{id}_k\}$, BS_N assigns dedicated data slots to each BS_k in the data transmission sub frame of the MAC UL management field. This information on data assignment is included in the UCD/UL-MAP field of the multicasting sub frame of the MAC DL management.
  - For each $\mathbf{TS}_m$, in its dedicated data slots, this contribution proposes that each BS_k transmits its $\mathbf{BS\_CT}^{(n)}_k$ in an incremental fashion (instead of providing the absolute value) as follows:

- Based on the knowledge of $\mathbf{P}^{min,(n)}_{m}$ and $\mathbf{P}^{max,(n)}_{m}$, BS_N proposes several pre defined Q discrete steps $\{S_{m,p}\}$ to facilitate each BS_k to express their relative increase between the iteration n-1 and n on $\mathbf{TS_m}$. Q is an integer. $\{S_{m,p}\}$ can be represented/coded by the following field (Figure 12):

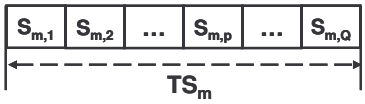

Figure 12: **MAC frame format - Sequence (6) - Pre defined Q discrete steps $\{S_{m,p}\}$ on TS_m**

- This field is multicast in the "multicasting sub frame" of the MAC DL management field as follows (Figure 13):

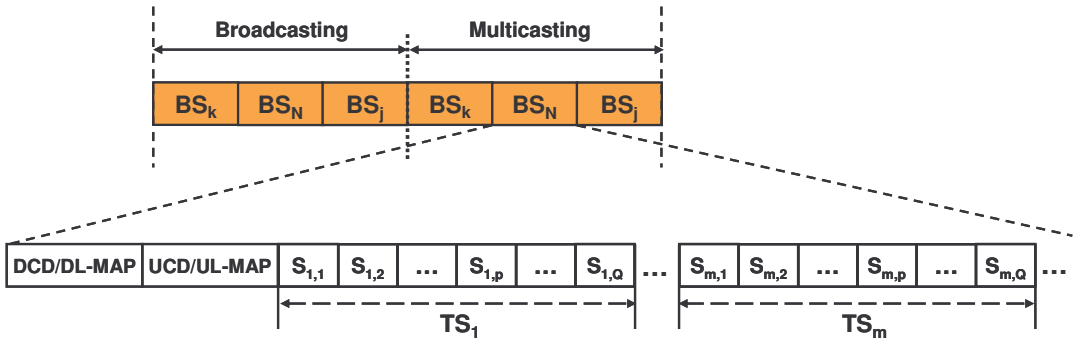

Figure 13: **MAC frame format - Sequence (6) - DL Multicasting**

- For each BS_k, this relative increase between the iteration n-1 and n is noted $\mathbf{\Delta}^{(n)}_{k}$ and can be expressed as follows: $\mathbf{\Delta}^{(n)}_{k} = \mathbf{BS\_CT}^{(n)}_{k} - \mathbf{BS\_CT}^{(n-1)}_{k} = \mathbf{a}_{k,1}\mathbf{S}_{m,1} + \mathbf{a}_{k,2}\mathbf{S}_{m,2} + \ldots + \mathbf{a}_{k,Q}\mathbf{S}_{m,Q} = \sum \mathbf{a}_{k,p}\mathbf{S}_{m,p}$ over all p, p varying from 1 to Q. Let be $\mathbf{A_k} = [\mathbf{a}_{k,p}]$.
- Each BS_k calculates eack $\mathbf{a}_{k,p}$ to reach $\mathbf{BS\_CT}^{(n)}_{k}$. Next, BS_k transmits $\mathbf{A_k}$ to BS_N in the data transmission field of the MAC UL management field as follows (Figure 14):

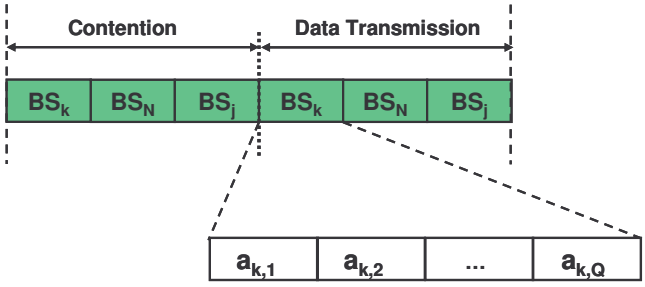

Figure 14: **MAC frame format - Sequence (6) - UL data transmission**

In the multicasting sub frame of the MAC DL management field, the UCD/UL-MAP provides the information to each BS_k from $\{\mathbf{id}^{(n)}_{k}\}$ at which moment each BS_k will be able to transmit its $\mathbf{A_k}$ in the data transmission field of the MAC UL management field. With respect to this, this contribution proposes that the data UL transmission field (Figure 14) is split into sub frames. Each sub frame is dedicated to a BS_k for the transmission of $\mathbf{A_k}$.

- The MAC frame mechanisms enabling sequence (7) is similar to sequence (5). The difference with sequence (5) is that now the MAC frame mechanisms enabling the transmission of $\{\mathbf{P}^{\mathbf{min,\ (n)}}{}_{\mathbf{m}}\}$ and $\{\mathbf{P}^{\mathbf{max,\ (n)}}{}_{\mathbf{m}}\}$ is implemented with an incremental mechanism as used in sequence (6). For each $\mathbf{TS_m}$, only the relative values (difference) $\mathbf{\Delta P^{min,\ (n)}_m = P^{min,\ (n)}_m - P^{min,\ (n-1)}_m}$ and $\mathbf{\Delta P^{max,\ (n)}_m = P^{max,\ (n)}_m - P^{max,\ (n-1)}_m}$ are transmitted in the "multicasting sub frame" of the MAC DL management field.

Final pricing and credit tokens transaction phase

This phase is composed of two sequences as follows:

- The MAC frame mechanisms enabling the transmission of this information $\{\mathbf{BS\_CPA_k}\}$ in sequence (8) are implemented in the multicasting field of the MAC DL management field.
- On the basis of the information sent in the multicasting field of the MAC DL management field in sequence (8), each BS_k confirms the billing transaction to pay $\mathbf{Pr_k}$. In sequence (9), this confirmation is transmitted in the data transmission field (Figure 5) of the MAC UL management field. Each sub frame is dedicated to a BS_k for the transmission of this confirmation. This confirmation is represented by a single bit ("0" for yes, "1" for no).

4 Conclusion

The topic addressed by this contribution is related to the cooperative based co-existence resolution and negotiation protocol. This contribution has provided MAC frame mechanisms enabling the over the air implementation of the different phases of the enhanced credit tokens based scheduling algorithm presented in [3]. With respect to this, DL (broadcasting, multicasting) and UL (contention, data transmission) management mechanisms have been proposed to manage dynamically the DL and UL of the MAC frame during the different phases of the scheduling cycle. The proposed implementation enables several auctioning/bidding phases in parallel (i.e. initiated by different master NWs). Even so the proposed implementation is over the air, the global shaping of the common MAC frame (position and duration of the MAC management sub frames within the all frame) will require wired information exchange between local BS databases via IP communication (via a server) between the involved NWs. The proposed mechanisms comes to the top of existing MAC frames structures, so they are applicable to facilitate the co-existence among license exempt based 802.16 systems, but also 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].

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

[3] IEEE C802.16h-05/036r1 - Proposal for enhanced credit tokens based co-existence resolution and negotiation protocol, 2005-07-11