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Title	Optional Downlink Switched Beam Support in IEEE802.16e OFDMA	
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Re:	P802.16e/D6 Ballot Resolution Committee Recirculation Announcement	
Abstract	Definition of new information element (IE) and Extended Subheader usage to support switched beamforming in downlink.	
Purpose	Optional support of new switched beam selection mechanism in downlink.	
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Optional Downlink Switched Beam Support in IEEE802.16e OFDMA

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1. Background

Smart antennas are widely used to steer the beam patterns toward individual users. Since smart antenna technologies yield not only the enhanced antenna gain but also the co-channel interference reduction, systems with antenna arrays can provide better network performance than those with omni or sector antennas do. Switched and fully adaptive beamforming are two major applications of the smart antenna systems and each has it's own advantages and disadvantages. In many cases switched beam forming is widely used in the downlink and adaptive beam forming is widely used in the uplink. Switched beam applications are considered by many to be a robust and cost-effective method of increasing capacity in cellular networks. In this contribution an efficient beam selection algorithm of downlink switched beam smart antenna system is proposed. In order to support the proposed algorithm, we don't need any physical changes or additions. We can reflect this contribution by defining a new information element (DL_SBF_Support_IE) and extending the usage of Extended Subheader.

2. Algorithm and Scenario

Downlink switched beam forming (SBF) may be supported in the AAS Zone of DL subframe which is indicated by the AAS_DL_IE. In the switched beam architecture, the best beam is chosen from a number of DL fixed steered beams. The most important task in designing the switched beam system is to develop an efficient method of beam selection in such a way that the BS can quickly and accurately switch to the correct beam, which covers the area where the MS belongs. The conventional beam selections are based on the BS's measurements such as the received signal strength indicator (RSSI) and the direction of arrival (DOA) using the uplink signal. But this contribution proposes a new switched beam selection algorithm in which MS determines the best beam and informs the beam index to BS so as for the BS to steer it to the corresponding MS.

In order to support for the MS to find the best beam among the fixed DL switched beams, the BS assigns a number of subchannels using DL_SBF_Support_IE in the DL AAS Zone. If the number of fixed downlink switched beams is *N*, then the subcarriers assigned using DL_SBF_Support_IE shall be divided into *N* groups. Subcarriers belong to *k*-th group shall be BPSK modulated by the specified data pattern and transmitted using *k*-th fixed DL switched beam. The MS shall choose the best beam in such a way that it estimates all the fixed DL switched beam powers using the subcarriers assigned to the corresponding beams and selects one that gives the maximum beam power. The selected beam index report to the BS can be performed using the DL Switched Beam Index Feedback Extended Subheader (See 6.3.2.2.7.2).

Figure 1 shows the concept of the proposed downlink switched beam forming.

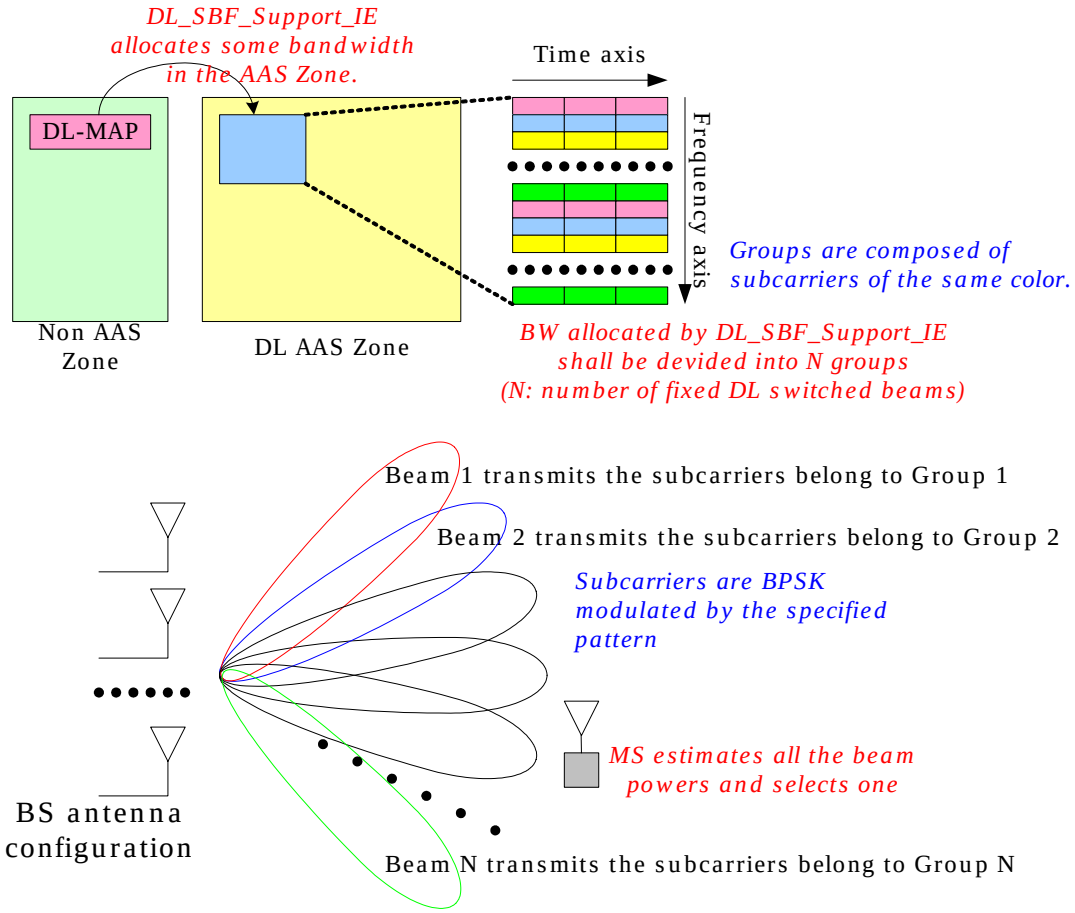

Figure 1: The illustration of the downlink SBF support.

The subcarrier grouping corresponding to each fixed DL switched beam is performed in the following manner:

- Renumber the subcarriers that are assigned using DL_SBF_Support_IE. The lowest frequency subcarrier on the lowest numbered OFDMA symbol in the allocated region shall be numbered to 1. The second lowest frequency subcarrier on the same OFDMA symbol shall be numbered to 2 and the following renumbering sequence shall advance in the same way.
- When reached to the highest frequency subcarrier of the lowest numbered OFDMA symbol in the allocated region, continue the renumbering from the lowest frequency subcarrier on the next lowest numbered OFDMA symbol.
- Each group for a corresponding switched beam shall be composed of the subcarriers having same index *j* defined by;

  $$j = i \bmod N, \quad i = 1 \ldots N \times \lfloor M/N \rfloor$$

  where
  i is the renumbered subcarrier index,
  M is the total number of subcarriers assigned by DL_SBF_Support_IE,
  N is the number of fixed DL switched beams.

The specified data pattern used to modulate the subcarriers assigned by DL_SBF_Support_IE shall be generated using the same PRBS used in ranging code generation. The first $N \times \lfloor M/N \rfloor$ bit code is taken and mapped to subcarriers assigned by DL_SBF_Support_IE. The MSB shall be mapped to the renumbered subcarrier #1. The LSB shall be mapped to the renumbered subcarrier # $N \times \lfloor M/N \rfloor$.

The MS shall estimate all the fixed DL switched beam powers. The instantaneous *k*-th beam power is the sum of all the received powers of subcarriers assigned to the beam.

$$P_{beam,k} = \sum_{l=1}^{L} P_{subcarrier,l} \ ,$$

where

$P_{beam,k}$ is the *k*-th beam power,

$P_{subcarrier,l}$ is the *l*-th received subcarrier power of *k*-th beam,

L is the total number of subcarriers assigned to *k*-th beam.

In order to enhance the beam selection accuracy, the mean of *k*-th beam power may be used. The *k*-th beam power may be defined by:

$$\mu^{k}_{BeamPower}[i] = \begin{cases} P_{beam,k}[0] & i = 0 \\ (1-\alpha_{avg})\mu^{k}_{BeamPower}[i-1] + \alpha_{avg} P_{beam,k}[i] & i > 0 \end{cases},$$

where

$\mu^{k}_{BeamPower}$ is the mean statistics of *k*-th beam,

i is the time index,

$P_{beam,k}[i]$ is the beam power measured at time index i.

The MS shall choose the best beam that gives the maximum beam power:

$$BeamIndex = \arg\max_{k} \left\{ \mu^{k}_{BeamPower} \right\}.$$

3. Advantages

Followings are the advantages of this algorithm:

- In the DOA-based algorithm there is a limitation to assign enough power to uplink signal for reliable DOA measurement because MS is powered by battery. On the other hand in this algorithm BS can assign enough power to downlink signals that helps the MS determine the best beam.
- Since the discrepancies associated with each antenna element are taken into account, the proposed switched beam selection algorithm does not need BS array transmitter calibration. Also this is very useful for FDD applications.
- In the conventional downlink switched beam algorithms, the BS is responsible for selecting the appropriate downlink beam for each target MS based on such uplink signal measurements as DOA and RSSI. But in the proposed algorithm every MS selects the downlink switched beam using the common downlink signal. So the proposed algorithm needs not to assign individual bandwidths in the uplink to MSs for the dedicated measurements of DOA and RSSI

4. Proposed text changes

[Change the Table 13c as indicated: Page 28, Line 60]

Table 13c – Description of extended subheaders (UL)

ESF bit	Name	Length (bytes)	Description
Bit #0 (LSB)	Mode selection feedback	1	See 6.3.2.2.7.1
~~Bits #1-10~~ Bits #1 Bits #2-10	~~Reserved~~ DL switched beam index feedback Reserved	1	See 6.3.2.2.7.2

[Make the new section 6.3.2.2.7.2 and insert the following text: Starting from the page 236 line 31]

--- Start Text

6.3.2.2.7.2 DL Switched Beam Index Feedback Extended Subheader

The format of the DL Switched Beam Index Feedback Extended Subheader is specified in Table 13f. The support of the DL Switched Beam Index Feedback Extended Subheader is limited to OFDMA. An MS uses the DL Switched Beam Index Feedback Extended Subheader to feed the selected beam index as specified in 8.4.4.7 back to BS.

Table 13f – DL Switched Beam Index Feedback Extended Subheader format

Name	Length (bits)	Description
Feedback content	16	Bit#0~7: DL switched beam index Bit#8~15: The band index to which MS prefers. This field is valid only when the AAS Zone is using the AMC. Shall be set to 0xFF when AMC is not used.

--- End Text

[Make the new section and insert the following text: Starting from the page 236 line 31]

--- Start Text

8.4.4.7 Optional DL Switched Beam Support

Downlink switched beam forming (SBF) may be supported in the AAS Zone of DL subframe which is indicated by the AAS_DL_IE. In the switched beam architecture, the best beam is chosen from a number of DL fixed steered beams. The most important task in designing the switched beam system is to develop an efficient method of beam selection in such a way that the BS can quickly and accurately switch to the correct beam, which covers the area where the MS belongs.

In this optional switched beam support, the MS determines the best beam and informs the selected beam index to BS so as for the BS to steer it to the corresponding MS. In order to support for the MS to find the best beam among the fixed DL switched beams, the BS assigns a number of subchannels using DL_SBF_Support_IE in the DL AAS Zone. If the number of fixed downlink switched beams is *N*, then the subcarriers assigned using DL_SBF_Support_IE shall be divided into *N* groups. Subcarriers belong to *k*-th group shall be BPSK modulated by the specified data pattern and transmitted using *k*-th fixed DL switched beam. The MS shall choose the best beam in such a way that it estimates all the fixed DL switched beam powers using the subcarriers assigned to the corresponding beams and selects one that gives the maximum beam power. The selected beam index report to the BS can be performed using the DL Switched Beam Index Feedback Extended Subheader (See 6.3.2.2.7.2).

The subcarrier grouping corresponding to each fixed DL switched beam is performed in the following manner:

- Renumber the subcarriers that are assigned using DL_SBF_Support_IE. The lowest frequency subcarrier on the lowest numbered OFDMA symbol in the allocated region shall be numbered to 1. The second lowest frequency subcarrier on the same OFDMA symbol shall be numbered to 2 and the following renumbering sequence shall advance

in the same way.

- When reached to the highest frequency subcarrier of the lowest numbered OFDMA symbol in the allocated region, continue the renumbering from the lowest frequency subcarrier on the next lowest numbered OFDMA symbol.
- Each group for a corresponding switched beam shall be composed of the subcarriers having same index *j* defined by;

$$j = i \bmod N, \quad i = 1 \ldots N \times \lfloor M/N \rfloor$$

where

i is the renumbered subcarrier index,

M is the total number of subcarriers assigned by DL_SBF_Support_IE,

N is the number of fixed DL switched beams.

The specified data pattern used to modulate the subcarriers assigned by DL_SBF_Support_IE shall be generated using the same PRBS used in ranging code generation. The first $N \times \lfloor M/N \rfloor$ bit code is taken and mapped to subcarriers assigned by DL_SBF_Support_IE. The MSB shall be mapped to the renumbered subcarrier #1. The LSB shall be mapped to the renumbered subcarrier # $N \times \lfloor M/N \rfloor$.

The MS shall estimate all the fixed DL switched beam powers. The instantaneous *k*-th beam power is the sum of all the received powers of subcarriers assigned to the beam.

$$P_{beam,k} = \sum_{l=1}^{L} P_{subcarrier,l} \text{ ,}$$

where

$P_{beam,k}$ is the *k*-th beam power,

$P_{subcarrier,l}$ is the *l*-th received subcarrier power of *k*-th beam,

L is the total number of subcarriers assigned to *k*-th beam.

In order to enhance the beam selection accuracy, the mean of *k*-th beam power may be used. The *k*-th beam power may be defined by:

$$\mu_{BeamPower}^{k}[i] = \begin{cases} P_{beam,k}[0] & i = 0 \\ (1-\alpha_{avg})\mu_{BeamPower}^{k}[i-1] + \alpha_{avg} P_{beam,k}[i] & i > 0 \end{cases},$$

where

$\mu_{BeamPower}^{k}$ is the mean statistics of k-th beam,

i is the time index,

$P_{beam,k}[i]$ is the beam power measured at time index i.

The MS shall choose the best beam that gives the maximum beam power:

$$BeamIndex = \arg\max_{k} \left\{ \mu_{BeamPower}^{k} \right\}.$$

--- End Text

[Make the new section 8.4.5.3.26 and insert the following text: Starting from the page 269 line 7]

--- Start text

8.4.5.3.26 DL Switched Beam Support IE

In order to support for the MS to find the best beam among the fixed DL switched beams, the BS assigns a number of subchannels using DL_SBF_Support_IE. The subchannel assignment using DL_SBF_Support_IE shall also be defined in the DL AAS Zone.

Table xxx – DL_SBF_Support_IE format

Syntax	Size	Notes
SBF_DL_Support_IE() {		
Extended DIUC	4 bits	DL_Switched_Beam_Support_IE
Length	4 bits	
Number of fixed DL switched beams	8 bits	The value of this field specifies the number of fixed downlink switched beams in this sector or cell.
if (AAS Zone = AMC[2×3]) {		
Band BITMAP	Nb-BITMAP bits	Bandwidth allocation to allow for MS to select the best when the AMC is defined in the AAS Zone. Setting the *n*-th LSB represents that the *n*-th band is selected. For each of the selected bands, the MS can choose the best beam. After evaluating all the selected bands, the MS knows not only the best beam of each band but also the most preferred band.
No. Subchannels	4 bits	
Padding nibble if required		
}		
else {		
OFDMA Symbol offset	8 bits	Bandwidth allocation to allow for MS to select the best when the non-AMC is defined in the AAS Zone.
Subchannel offset	8 bits	
No. OFDMA Symbols	4 bits	
No. Subchannels	4 bits	
}		
}		

--- End text ----------