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Re:	802.16m-08/033, “Call for Contributions and Comments on Project 802.16m System Description Document (SDD),” ♦ PHY: Multi-Carrier Operation
Abstract	This contribution aims to investigate the possible problems when perform data transmission over guard sub-carriers and to propose feasible PHY and control structures for guard sub-carriers.
Purpose	To facilitate the harmonization on multi-carrier operation for TGm
Notice	
Release	
Patent Policy	

Physical and Control Structure to Support Data Transmission /Reception over Guard Sub-carriers in IEEE 802.16m

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I. Introduction

In order to fulfill the IMT-Advanced requirements to support different bandwidth allocation required by different operators and different countries, IEEE 802.16m shall support the scalable bandwidth allocation from 5MHz to 40MHz and it may be achieved by single or multiple RF carriers. The most suitable transmission architecture is to allow BS equipping a single RF carrier with wider channel bandwidth (e.g. 40MHz), while the MS equip multiple RF carriers with narrower channel bandwidth (e.g. 10MHz to facilitate backward compatibility). Because the BSs have to serve multiple MSs over different frequency channels simultaneously, having a single wide-band transceiver will be vary flexible for BS to coordinate this kind of the point-to-multi-point (PMP) data transmission.

On the other hand, the traffic demands by each MS and the affordable hardware complexity for each MS are usually much lower than BS. Therefore, it's not reasonable for most MSs to equip the wide-band transceiver. Having single or multiple narrow band transceivers with the same channel bandwidth as legacy system (i.e. 10MHz) in MS terminal is much desired to balance the MS traffic demand, hardware complexity and backward compatibility. Therefore, the transceiver architecture and the transmission scheme in Figure 1 is desired and be the reference model when discussing the guard sub-carrier data transmission problems in this contribution. Some detailed transceiver design problems for this architecture had been investigated in [1], this contribution will not address each of the detail problem but overview the possible architectures for references.

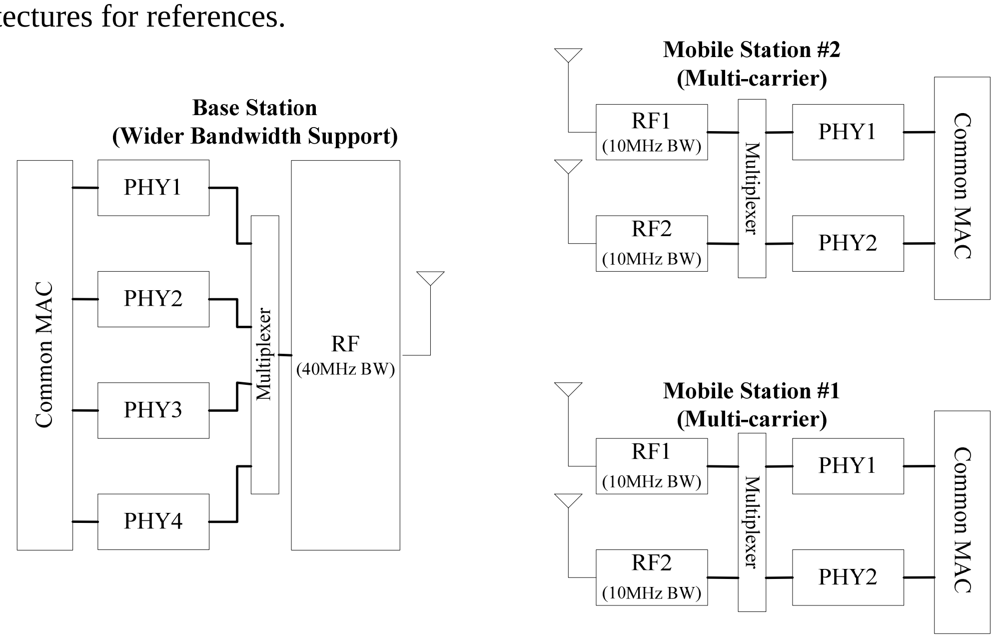


Figure 1(a) An example of the transceiver architecture of the BS with wider bandwidth and the multi-carrier MSs to support scalable channel bandwidth

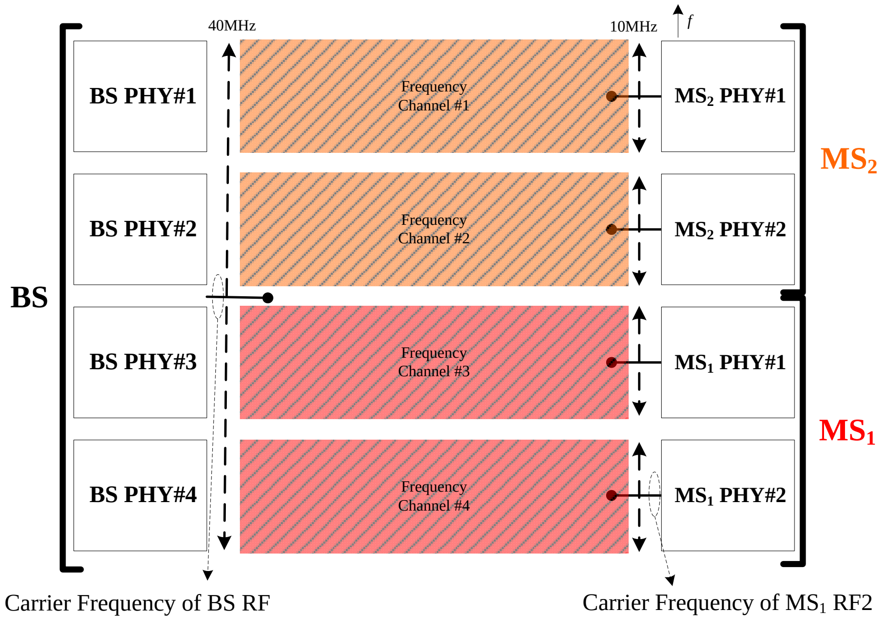


Figure 1(b) Wider bandwidth BS communicates with multi-carrier MSs over different frequency channels

II. Possible MS Transceiver Architectures to Support Guard Sub-carriers Transmission/Reception

Transceiver design is usually a proprietary issue out of the standardization scope, but sometimes members have to preliminarily investigate the feasible transceiver architectures before making some important technical decisions. Especially when standardizing the new technologies like multi-carrier transmission to support scalable channel bandwidth.

Figure 2 shows the first example (i.e. Type-I) on transceiver architecture to support data transmission/reception over guard sub-carriers [2]. In this example, MS can perform data transmission/reception over two RF carriers with a little bit wider bandwidth (e.g. 10~12MHz) than the legacy bandwidth (i.e. 10MHz). This is to receive the data transmitted over the guard sub-carriers at the two sides of the frequency channel. In addition to the MS PHY#1 and #2 to receive the data transmitted through the normal carriers in frequency channel#1 and #2, MS can use additional sub-PHY to decode the data transmitted over the guard sub-carriers in frequency channel#1 and #2 respectively. To enable this kind of scheme, different RF filter and digital baseband designs will be required and some aliasing cancelation techniques have to be applied.

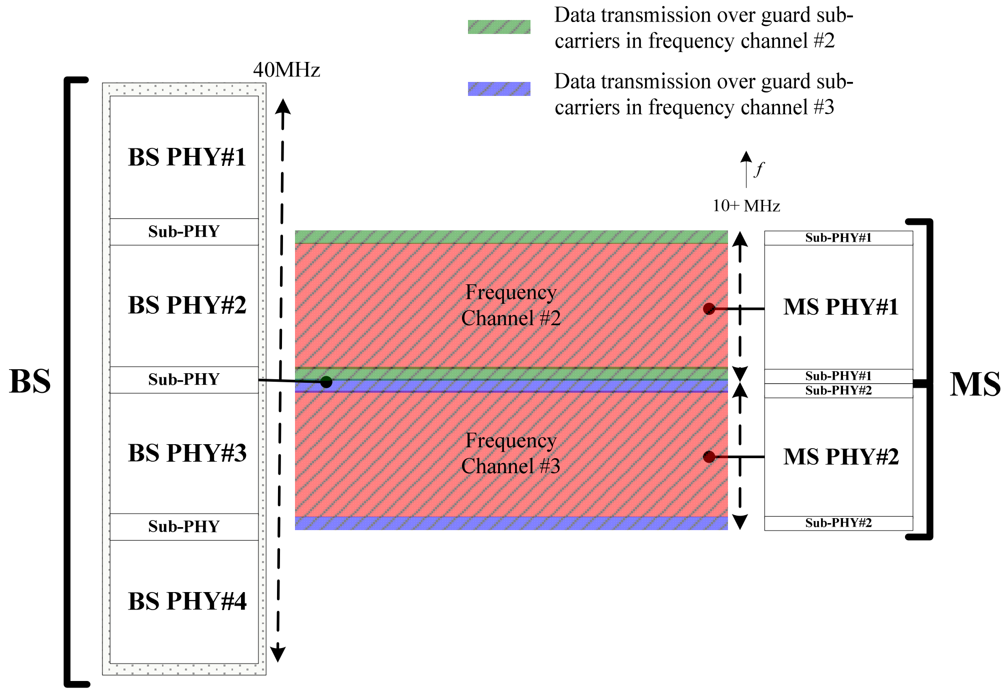


Figure 2 An example for data transmission over guard sub-carriers: Type-I

Figure 3 gives an example on Type-II which is very similar to the Type-I, where the receiver bandwidth is the same as the normal case (i.e. no guard sub-carrier data transmission). If the BS wants to perform data transmission over guard sub-carriers with Type-II MS, MS may use its unused transceiver (i.e. MS PHY#2) to transmit/receive data over the guard sub-carriers like the transmission over the secondary carriers (with smaller bandwidth) [3]. To enable the Type-II guard sub-carrier transmission, MS doesn't need to change its RF filter bandwidth and able to directly reuse the design for normal case. The additional work for decoding the data in guard sub-carriers is additional post-FFT digital processing. The additional effort depends on how much different the PHY structure for guard sub-carriers is. To support this type, one of those guard sub-carriers between adjacent normal carriers has to be DC sub-carriers.

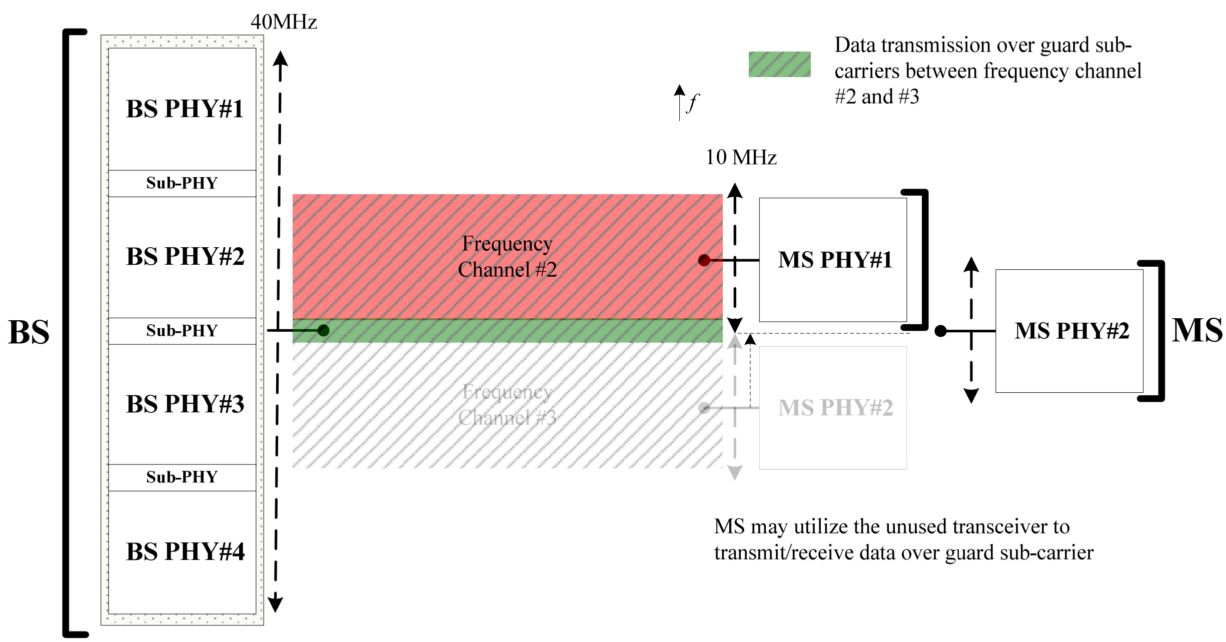


Figure 3 An example for data transmission over guard sub-carriers: Type-II

Figure 4 shows the Type-III example for MS to transmit/receive data over guard sub-carriers, which actually uses the wider bandwidth transceiver rather than multi-carrier [4]. Since this had been proposed by some members, this section also investigates the possible guard sub-carrier transmission scheme for this scenario. As depicted in Figure 4, the MS has 20MHz RF filter bandwidth and decode the data in guard sub-carriers by post-FFT digital processing. In order to enable this scheme, the RF filter bandwidth will be different than the legacy one and larger size FFT has to be chose. The post-FFT processing will be the same as the case for Type-II and will also similar with the post-FFT part in Type-I. For this type, the center sub-carrier of those guard sub-carriers between two normal carriers has to be DC sub-carrier.

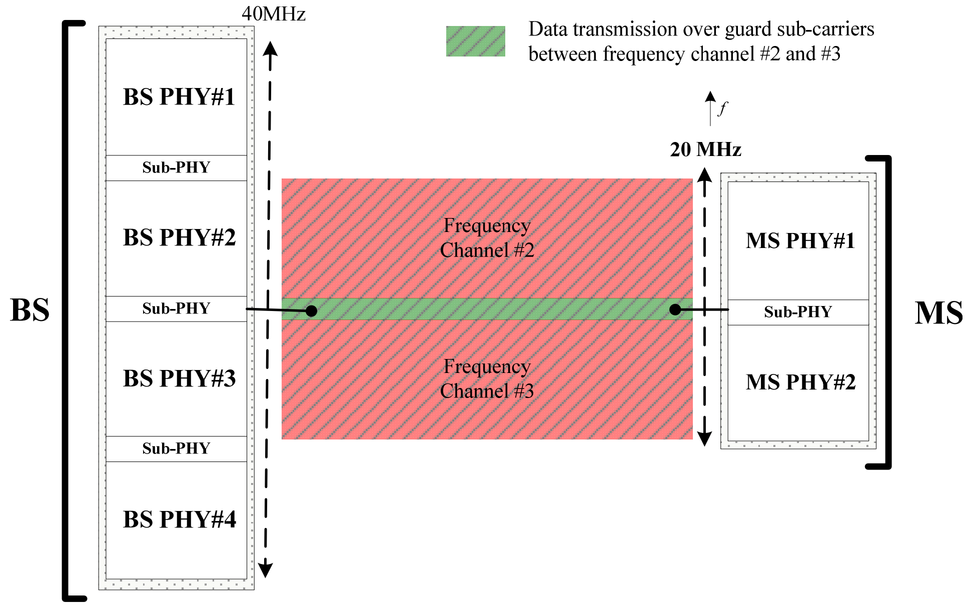


Figure 4 An example for data transmission over guard sub-carriers: Type-III

The flexibility for BS scheduling when supporting different types of MS

There are many tradeoffs for implementing the aforementioned three types of MS to support guard sub-carrier transmission. However, the transceiver architecture is not only relevant to guard sub-carrier data transmission but also relevant to the restriction on system operations. The following tries to provide preliminary investigation from the view point on the flexibility for BS scheduling.

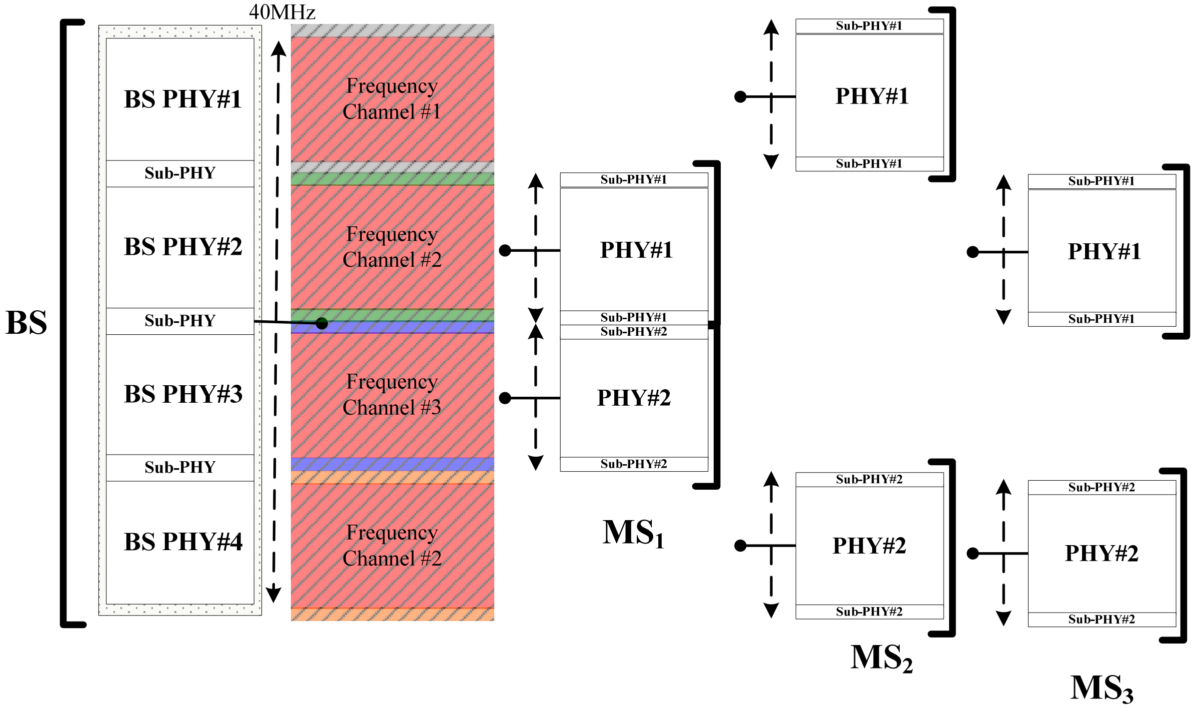


Figure 5 BS Scheduling flexibility when supporting Type-I MS

Figure 5 and Figure 6 show the examples on how flexible the BS may schedule the Type-I and Type-II MSs. Since the transceiver bandwidth is basically in unit of the bandwidth of individual frequency channel, the BS can take advantage of the multiple RF carriers to serve MS in non-contiguous frequency channels to explore more multi-user diversity gain and better efficiency for load balancing. The flexibility can be further outperformed by Type-II MS, where the MS can use specific baseband receiver to transmit/receive the data over all the guard sub-carriers between the adjacent normal carriers.

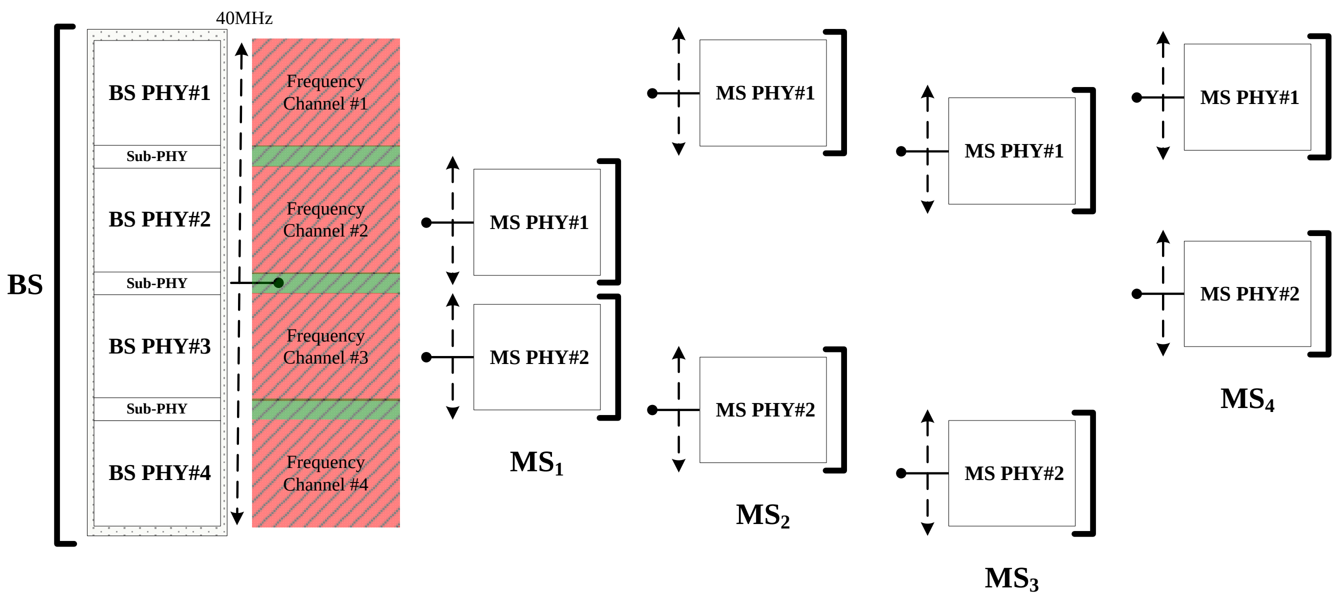


Figure 6 BS Scheduling flexibility when supporting Type-II MS

In Figure 7, an example on BS scheduling flexibility when supporting Type-III MS is given. Due to the restriction of wider bandwidth receiver, the BS cannot schedule the MS be served by non-contiguous frequency channels and the MS can only transmit/receive data over the guard sub-carriers between the adjacent frequency channels in use.

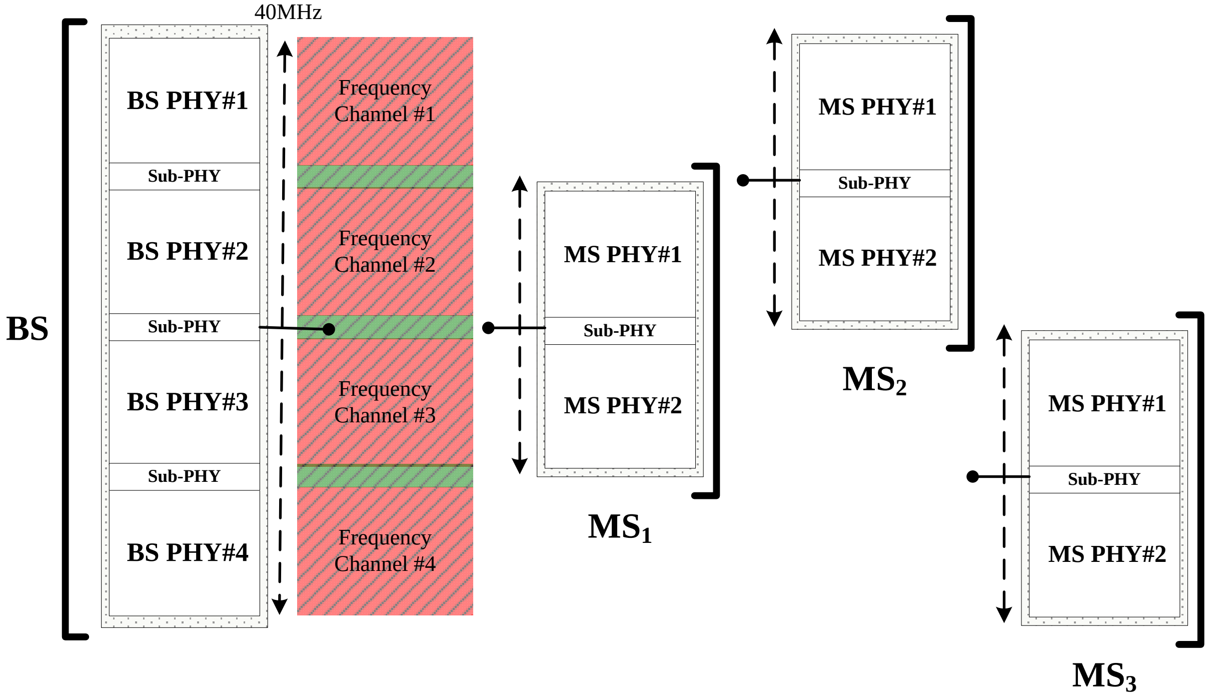


Figure 7 BS Scheduling flexibility when supporting Type-III MS

Note that the objective of this section is not to judge which transceiver architecture is the best solution, but to investigate the possible transceiver architectures to be considered in IEEE 802.16m to support scalable bandwidth and multi-carrier operation. The discussion in this section will be the references when investigating the feasible PHY and Control structure design for guard sub-carriers to support data transmission.

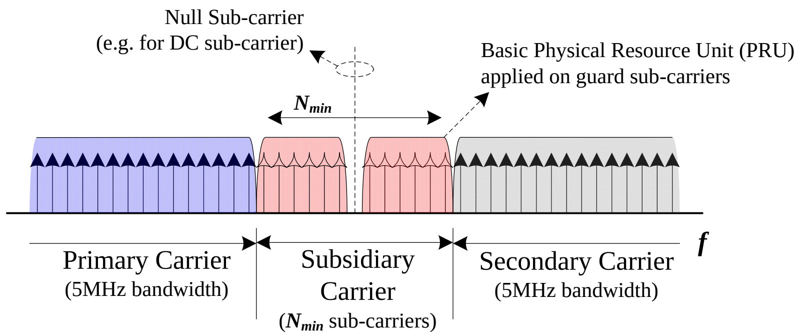
III. Recommended Control Structure

According to the possible transceiver architectures discussed in previous section, this section tries to investigate the reasonable PHY and Control structure to support the data transmission over guard sub-carriers. Please note that the assumption of the following discussion is that the sub-carriers of the radio signals transmitted over adjacent carriers (i.e. frequency channel) are well aligned in frequency domain. The detail of the sub-carrier alignment mechanism can refer to section 19.2 in P802.16m SDD.

PHY Structure Design for Guard Sub-carriers

According to the Type-II and Type-III MS discussed in previous section, the system shall reserve at least one sub-carrier to be the DC sub-carrier when performing the data transmission over guard sub-carriers. Due to the limited number of available guard sub-carriers between adjacent carriers eligible for possible data transmission, the size of physical resource unit (PRU) and the suitable logical resource unit (LRU) shall be properly designed. First, the maximum size of physical resource unit (PRU) used for guard sub-carriers shall be smaller than $(N_{min}$-1)/2, where N_{min} is the minimum number of available guard sub-carriers between adjacent carriers eligible for possible data transmission. In order to simplify the following introduction, the PRU transmitted over the guard sub-carriers is called GPRU (Guard sub-carrier PRU).

Example I:
The adjacent carriers with the minimum bandwidth (i.e. 5MHz)



Example II:
The adjacent carriers with the bandwidth are larger than minimal bandwidth (e.g. 10MHz)

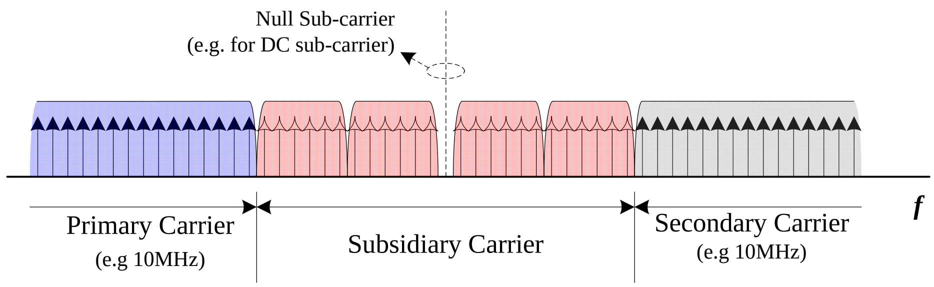


Figure 8 Example on PHY structure for guard sub-carrier to support data transmission

Figure 8(a) shows an example of the PHY structure for guard sub-carriers to support data transmission when the bandwidths of adjacent carriers (i.e. frequency channels) are both the minimal bandwidth (i.e. 5MHz). The number of guard sub-carriers eligible for data transmission will be the minimal value in this case (i.e. N_{min}). For the ideal case, the DC sub-carrier is reserved at the center among those guard sub-carriers. The number of available guard sub-carriers to compose two GPRUs symmetric to the DC sub-carrier can be maximized in this case. Therefore, the size of GPRU applied in guard sub-carriers shall be smaller than (N_{min}-1)/2.

Since the number of sub-carriers used in normal carriers has not been determined, TGm may not determine the size of GPRU at this stage. But it will be highly desired if the format of GPRU applied for those guard sub-carriers will be the same as the one applied for normal carrier (i.e. 18×6 in DL, 18×6 or 18 ×6 in UL). This can reduce the additional effort on hardware design in order to support data transmission over guard sub-carriers.

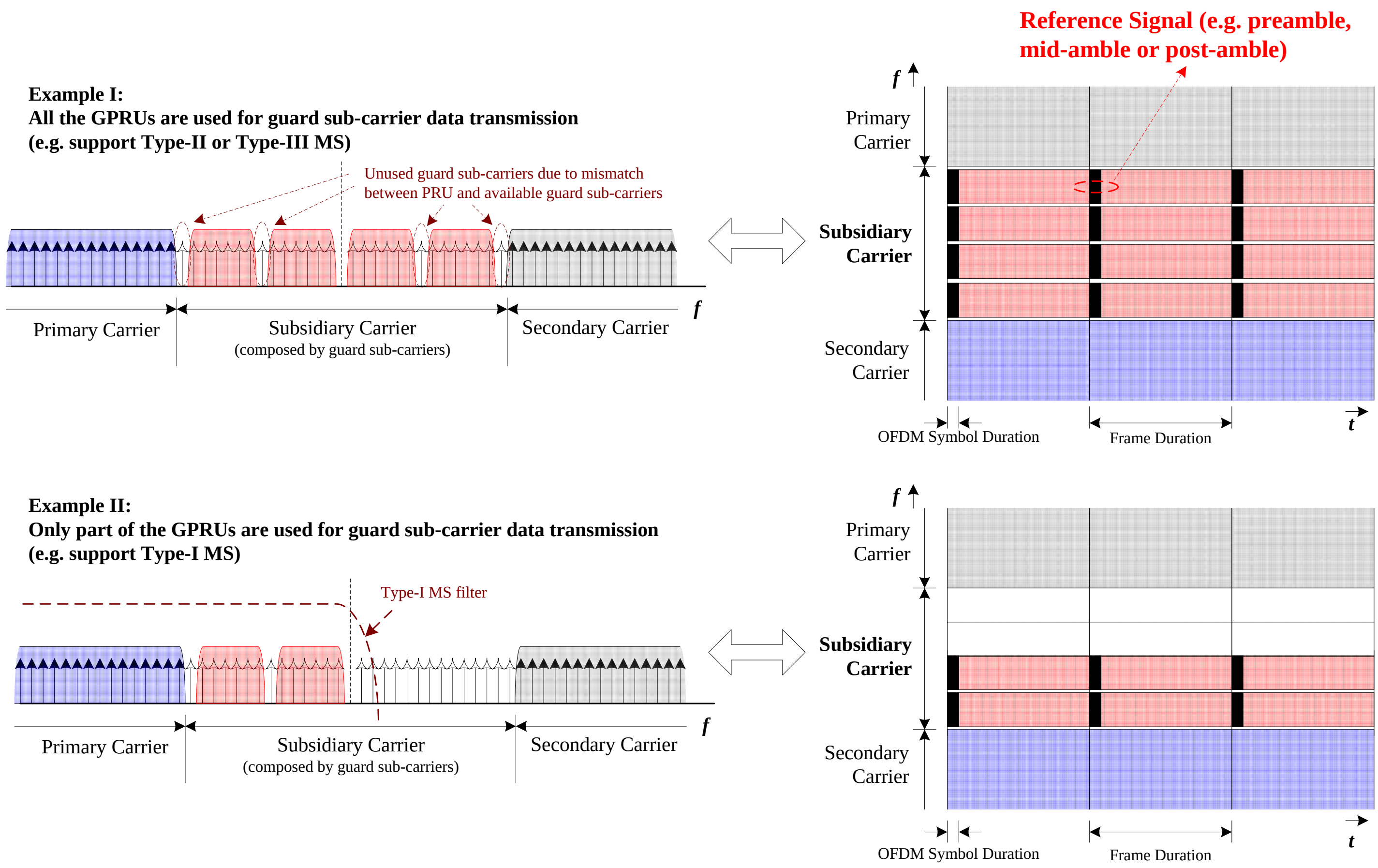
There is no specific recommendation on the logical resource unit (LRU) design to support guard sub-carrier data transmission in this contribution. Either distributed resource unit (DRU) or localized resource unit (LRU) are both possible, but the LRU may be more preferred due to the limited number of guard sub-carriers eligible for data transmission.

Another problem when supporting guard sub-carrier data transmission comes from the uncertainty on available guard sub-carriers between adjacent carriers eligible for data transmission. There are few reasons that will result in this situation:

1) <u>Different combinations of the channel bandwidths for adjacent carriers.</u> This is because the number of guard sub-carriers reserved for the channels with different bandwidth is usually different. One example is depicted in Figure 8, and some detailed explanation can be found in [1].
2) <u>Mismatch between the size of GPRU and the number of guard sub-carriers eligible for data transmission.</u> Reusing the GPRU format as the one in normal carrier can substantially reduce the implementation overhead. But it may also result in some restriction on utilizing the limited number

of guard sub-carriers. Since the data transmission over guard sub-carrier is a new technique for IEEE 802.16m, reusing the same format to simplified hardware design will be preferred for the first step.

3) Restrictions on receiver capability. For example, Type-I MS may not be able to receive data from all the guard sub-carriers due to the bandwidth of analog filter. Data may only be transmitted over part of the PRUs to facilitate data reception. On the other hand, system may specifically reserve some guard sub-carriers between those transmitted GPRU and normal carrier to mitigate some potential interference. The detail and possible still need further study, and the MS shall negotiate its capability with the serving BS in advance.



(a) (b)

Figure 9 (a) Examples on different GPRU transmission locations to support different type of MSs, (b) using the reference signal to help MS identify the location of GPRU to facilitate data reception.

Figure 9(a) shows several examples that the GPRU location may be different from one case to another, and the MS has to know its location exactly for data reception. One way to help MS explore the exact location of GPRU is using MAC messaging via primary carrier, but this may be complicated since different MS may have different capability and the GPRU location may be changed from time to time. A simpler way is putting some reference signal over the locations where GPRU will be transmitted, and the BS only need to inform MS if it needs to receive data from guard sub-carriers (i.e. subsidiary carrier). The reference signal can also be used for channel estimation or for other purposes. The format of the reference signal and the way to transmit it are still for further study.

Control Structure Design for Guard Sub-carriers

In order to control and manage the GPRU transmission over guard sub-carriers, there shall be a different carrier classification in addition of current classifications on primary and secondary carriers. Because the guard sub-carrier data transmission may not be enabled when serving for each MS and the number of guard sub-carriers eligible for data transmission may be different case by case, reusing the current carrier classifications will over define the capability of transmission over guard sub-carrier.

Figure 10 shows the basic idea of the classification, where the concept of the "subsidiary communication" had been applied in FM radio systems for a long time. The idea is treated the communication channels over guard sub-carriers as the supplemental enhancement of the IEEE 802.16m system. So the recommendation is to define a new type of carrier called "subsidiary carrier", which is composed by the sub-carriers which were originally reserved as the guard sub-carriers.

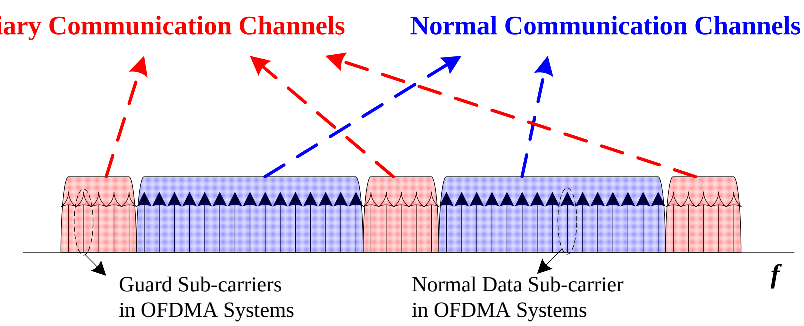


Figure 10. Basic idea of the subsidiary communication

There may exist different usages of the subsidiary carrier. For example, the subsidiary carrier can be a small data pipe to serve specific MS to share the traffic loading in primary or secondary carrier. On the other hand, the subsidiary carrier can also be a special signaling channel to periodically broadcast some control information to MS. One example is sending the paging signal or traffic indication signal to the idle mode or sleep mode MS. MS can also save more processing power by monitoring the subsidiary carrier which has much smaller bandwidth. Therefore, it is necessary to identify an additional carrier (i.e. subsidiary carrier) to control and indicate the transmission over guard sub-carrier.

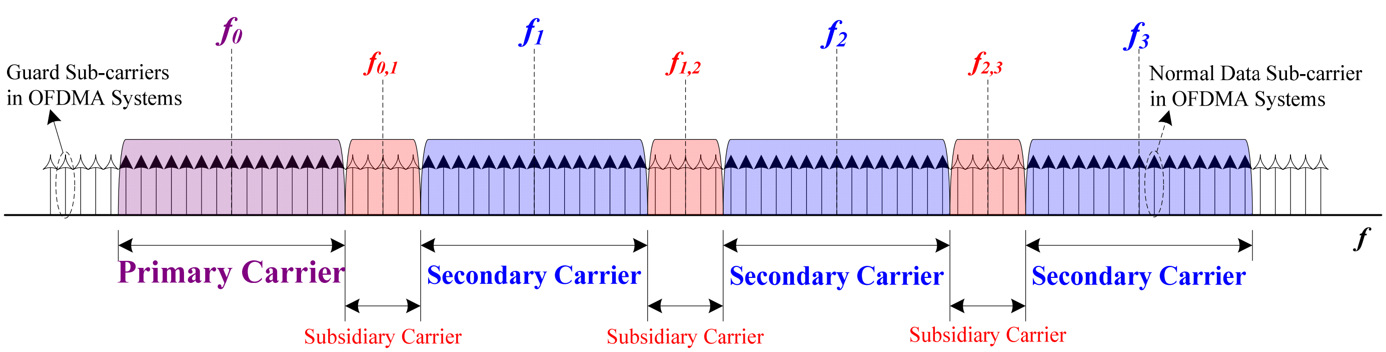


Figure 11. Recommended carrier classification for IEEE 802.16m

Figure 11 shows an example to classify the carriers into primary carrier, secondary carrier and the subsidiary carrier. According to this classification, BS can broadcast the PHY parameters relevant to guard sub-carrier data transmission to facilitate MS operation. Since the bandwidth available for subsidiary carrier is very limited, the scheduling and resource allocation information relevant to subsidiary carrier transmission should be broadcasted over primary or secondary carrier. Figure 12 shows an example to configure the data transmission not only in primary and secondary carriers but also in subsidiary carriers. Note that the detail control format and the operation of the subsidiary carrier is FFS.

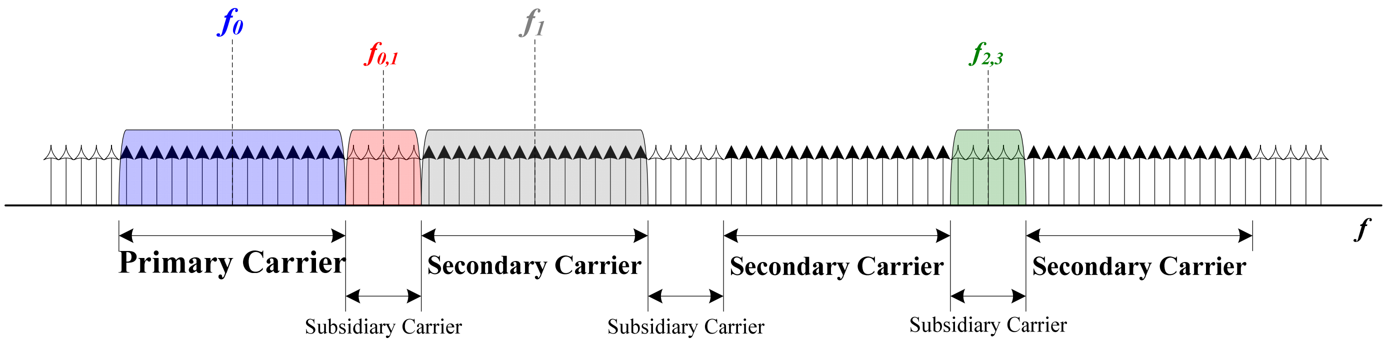


Figure 12. An example of the carrier configuration for specific multi-carrier MS

IV. Text Proposal

---Start of the Text--
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[Add the a new section 11.5.4 and the following after line#9 page#51]
11.5.4 Support for Transmission over Guard Sub-carrier

[Add the a new section 11.6.5 and the following after line#22 page#55]
11.6.5 Support for Transmission over Guard Sub-carriers

[Apply the following text modification since line#5, page#64 of IEEE 802.16m-08/003r4]
The carriers involve in a multi-carrier system, from one MS point of view, can be divided into ~~two~~ three types:

- A Primary carrier is the carrier used by the BS and the MS to exchange traffic and full PHY/MAC control information defined in 16m specification. Further, the primary carrier is used for control functions for proper MS operation, such as network entry. Each MS shall have only one carrier it considers to be its primary carrier in a cell.

- A Secondary carrier is an additional carrier which the MS may use for traffic, only per BS's specific allocation commands and rules, typically received on the primary

- A Subsidiary carrier is the carrier which composed by the sub-carriers which were originally reserved as guard sub-carriers. BS may schedule the MS be served by subsidiary carrier though the messaging in primary carrier.

[*Apply the following text modification over line#20, page#64 of IEEE 802.16m-08/003r4*]
A primary carrier shall be fully configured while a secondary carrier may be fully or partially configured depending on usage and deployment model. The subsidiary carrier will always be partially configured.

---End of the Text---

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Reference

[1] Youngsoo Yuk et al, "The PRU Configuration for BW Aggregation," IEEE C802.16m-08/802r3, July 2008.
[2] Kwanhee Roh et al, "Proposed 802.16m Resource Allocation Scheme Using Additional Subcarriers in Guard Band," IEEE C802.16m-08/209r2, March 2008.
[3] I-Kang Fu et al, "Subsidiary Communication by using Guard Sub-carriers in IEEE 802.16m," IEEE C802.16m-08/561, July 2008.
[4] Hujun Yin et al, "Virtual Multi-Carrier Operation for IEEE 802.16m," IEEE C802.16m-08/364, May 2008.