Two-Level Carrier Sensing in Overlapping Basic Service Sets (BSSs)

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1. Novelty

The rapid growth of wireless communication technologies has pushed the standardization of corresponding protocols. Currently, a series of protocols have been proposed and standardized for IEEE 802.11 family. Among them, 802.11 is the first standard for the objective to develop a medium access control (MAC) and physical layer (PHY) specification for wireless connectivity for fixed, portable, and moving stations within a local area. Following the original 802.11, the 802.11 working group (WG) has continued to issue extensions and amendments of the standard. So far, the letters "a" through "n" have been officially designated to task groups (TGs) within the 802.11 WG. Right now, TGn has aimed at provide throughput up to 100Mbps or higher in WLAN.

The IEEE 802.11 architecture consists of several components that interact to provide a wireless LAN. Basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Both independent BSS (IBSS) and overlapping BSS may exist in a wireless LAN. Current 802.11 series protocols are suitable for communications in IBSS, however, based on current protocol, for overlapping BSS scenario, if two PCs operate on the same channel, collision will occur and the network performance will be degraded significantly. We hereby propose a novel two level carrier sensing mechanism for overlapping BSSs scenario to achieve efficient channel utilization by reducing the possible collisions between STAs from different BSSs. The station (STA) will adjust its network allocation vector (NAV) based on both the legacy carrier sensing mechanism and proposed two level carrier sensing following the rules specified in this document. The proposed mechanism can maintain efficient channel usage through implicit scheduling --- most collisions due to overlapping BSSs are avoided by setting appropriate deferral for each STA in the network.

2. Technical Discloser

2.1 Background

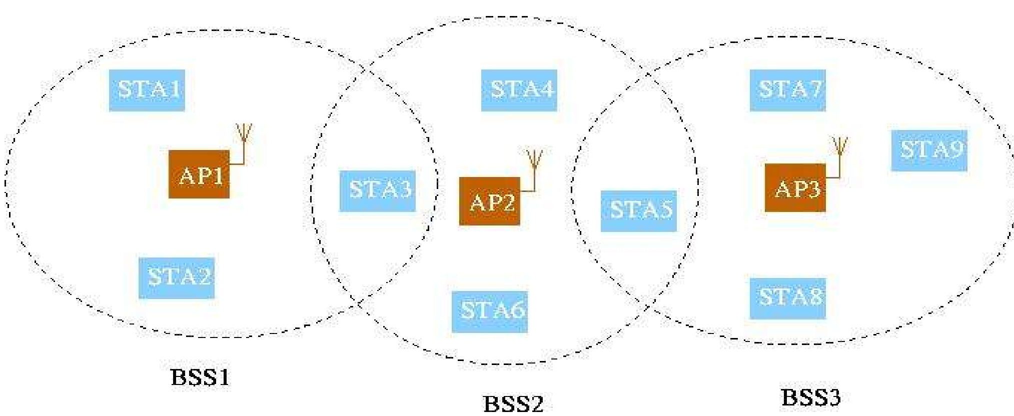


Figure 1: An example of overlapping BSSs

Overlapping BSS problem is very common in cellular and wireless local area networks. In the context of this document, we focus on the overlapping BSS problem in WLAN. Overlapping BSS problem refers to the situation that two or more systems, unrelated to each other, are in close enough proximity to hear each other physically. Once they are running at the same channel, the transmission by some STAs belonging to one BSS will affect the STAs in the other BSS.

Figure 1 depicts an example of overlapping BSS problem of three BSSs. Under the assumption that these three BSSs operate at the same channel, collisions will happen between BSSs even appropriate scheduling inside single BSS is present. For example, suppose STA3 is associated and polled by AP1, its transmission will interfere with transmissions in BSS2, even though BSS2 is in contention free period, hence the network performance will be degraded significantly.

2.1.1.Three Possible Situations of Overlapping

In this subsection, we illustrate three different network configurations of overlapping BSSs. These examples will facilitate us to (1) enumerate all the problems that arise when two BSSs are overlapped, and (2) explain the solutions to handle them. During the rest of this document these situations will be referred constantly to illustrate the problems and solutions.

In the following examples, we use the same expression as in [3] to label the STAs. For example, $STA_{x,1}$ belongs to the BSS of AP_x, which is called BSS_x, STAs (and APs) can hear every one in their transmission range but can only transmit to the STAs that is associated in the same BSS.

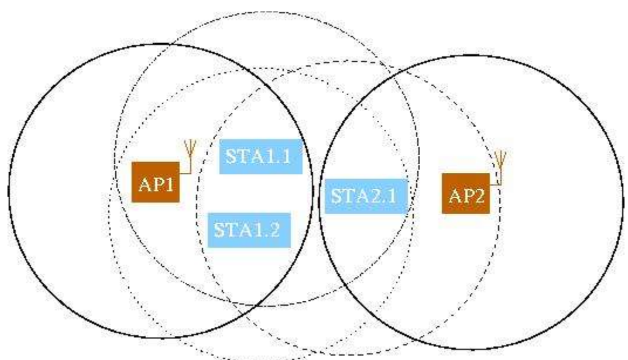


Figure 2: Situation A of overlapping BSSs, $STA_{2.1}$ is not reachable form AP_1

Figure 2 - 4 illustrate the three situations of overlapping BSSs, namely, situation A, B and C. Figure 2 depicts Situation A --- in this scenario that the coverage of two BSSs are not overlapped, however, the transmission range of some STAs in one BSS (e.g. $STA_{1.1}$ and $STA_{1.2}$ in BSS_1) overlaps with transmission range of STAs in the other BSS (e.g. $STA_{2.1}$ in BSS_2). Although this situation is not a typical case of overlapping BSSs, however, the transmission in one BSS may also affect with the transmission in the other BSS, hence in this document, situation A can be also called overlapping BSSs; in fact, it is the most problematic situation of the three, since comparing to the 2 other situations, in situation A, inter-BSS interference is present, however, it is difficult to for the AP and STAs in different BSSs to obtain information of the potential interference. In order to solve this overlapping BSS problem, RTS/CTS in contention free period (CFP) scheme proposed in [1] will be helpful.

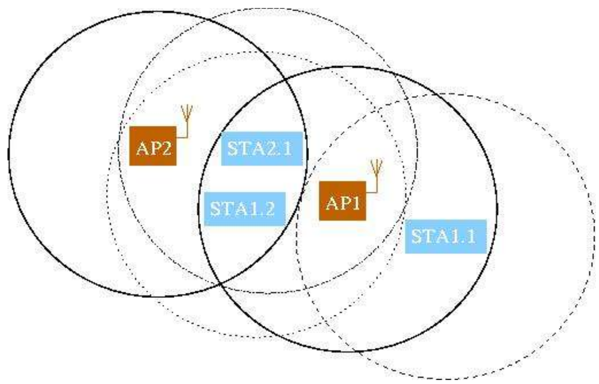


Figure 3: Situation B of overlapping BSSs; $STA_{1.1}$ is reachable from AP_2

Figure 3 depicts another situation of overlapping BSSs problem, in which the STA in one BSS (e.g. $STA_{1.1}$ and $STA_{1.2}$ in BSS_1) are able to hear transmission from the AP of the other BSS (e.g. AP_2 in BSS_2). In this situation, the coverage areas of the BSSs are indeed overlapped. In situation B, the proposed two-level carrier sensing is useful to make appropriate deferral in corresponding BSSs, thus the overlapping BSSs are able to share the channel with reduced collision probabilities.

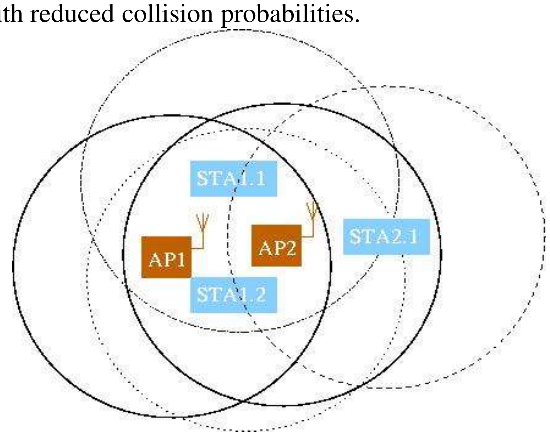


Figure 4: Situation C of overlapping BSSs; both APs can reach to each other

Figure 4 shows the third situation of overlapping BSSs --- situation C, in addition to the overlapping coverage area of BSSs, APs can hear each other and will have the information about the other BSS, and hence a good scheduling algorithm is capable to reduce the potential collision between STAs from different BSSs in CFP.

In this subsection the possible overlapping BSSs scenarios are enumerated, although there are some possible mechanisms to remedy the interference among overlapping BSSs, none of them can solve all the problems. Solutions capable to solve one scenario are not capable to solve the problems in other scenarios. In this document, the proposed solution is suitable for all the above situations; and with the help of other scheme, (for example, the RTS/CTS exchange proposed in [1] and scheduling scheme in [4]), the proposed mechanism can solve the overlapping BSSs problems in most cases.

2.2 Current Solutions for Overlapping BSSs

The collisions and interference among STAs caused by the overlapping BSSs problem will cause the unnecessary waste of channel resource. Hence the objective of the solution for such problem is to utilize the channel efficiently: transmit as much as possible and at the same time, do not waste resource on collision and retransmission. The BSSs should be able to manage the situation of overlapping by sharing the wireless channel fairly, preferably with a distributed mechanism. Until now, although some solutions have been proposed for scenarios like CFP overlapping CP BSSs [1][2][3], for scenario such as overlapping BSSs that both operate in CFP, it can only be handled by selecting different frequency channels. However, it is very desirable that BSSs can share a single frequency channel without performance compromise. Thus, A scheduling algorithm based on the theory of games has been proposed in. However, this solution only works when two overlapping APs can hear each other (e.g. situation C). It is not applicable for overlapping BSSs with APs can not hear each other, since this solution requires more communications among overlapping APs, which will increase the overhead. Moreover, with the demand of higher throughput, more throughput effective mechanisms such as multi-polling will be employed, however, to the best of our knowledge, there is no solution available for overlapping BSSs in multi-polling system. In this document, we propose that two-level carrier sensing should also be used in CFP in order to reduce the collision between overlapping BSSs, furthermore, the proposed solution is backward compatible with legacy MAC, when there is no overlapping BSSs, the proposed scheme doesn't affect the legacy two-level carrier sensing at all.

2.3 Limitations of Current Solutions

The existing solutions doesn' fit the requirement and the proposed mechanism of 802.11n, for example, in order to improve the efficiency of contention free period, multi-polling mechanism has been proposed by several TGn members and has great opportunity to be standardized finally, however, among the current solutions for overlapping BSSs, none considers how to react under multi-polling mechanism. Moreover, the available solutions can only solve problems of special cases, for example, the mechanism proposed in [3] can only work when one of the overlapping BSSs is in CFP while the other is in CP, if both of them are in CFP, collision will still happen, moreover, the solution in [3] requires different operations at CP and CFP, this requirement imposes unnecessary implementation complexity; the scheduling scheme [4] will only work in situation C, when two APs can hear each other thus scheduling is possible. Thus, it is necessary for the TGn group to have an universal solution for overlapping BSSs problem in both CP and CFP as well as suitable for the multi-polling mechanism which is important for high throughput wireless LAN.

2.4 Proposed Solution

We propose to solve the problem through two-level carrier sensing for both CP and CFP (notice that for legacy 802.11, there is no PHY sensing during CFP), the proposed solution is built on top of the ACK/Restart counting mechanism proposed by MERL. This relation makes the AP be able to react with idle channel more efficiently thus reduce the waste of resource as much as possible. Similar to IEEE 802.11, we will also employ carrier sensing at both PHY and MAC layer, the carrier sensing at PHY layer is simple --- don' transmit if a STA detect the channel is not idle, for MAC layer, virtual carrier sensing similar to 802.11 standard is employed --- in addition to original NAV, we propose use two of network allocation vector SBNAV (self-BSS network allocation vector) and OBNAV (overlapping-BSS network allocation vector). The original NAV then is set to be the either SBAV or OBAV, whichever is bigger. Among those two network allocation vectors, SBNAV is just the NAV in legacy IEEE 802.11, while OBNAV is set to 0 when there are no overlapping BSSs in the network and set to corresponding duration when there is overlapping BSS at present. In section 3 the details of the proposed mechanism is provided. But first in next subsection the MERL's proposal on ACK/Restart count in multi-polling environment (more specifically, MERL's proposed sequential coordinated channel access, SCCA) that serves as the underlying multi-polling scheme wherever multi-polling is employed.

2.5 MERL's proposal on SCCA and ACK/Restart Count in Multi-polling Environment

As mentioned in section 2.4, the multi-polling mechanism we consider in this document (whenever needed) is SCCA + ACK/Restart count multi-polling scheme [5][6]. This subsection gives a brief introduction of this mechanism. For the reset of this document, the SCCA+ACK/Restart count multi-polling scheme is assumed operating under CFP.

SCCA is a multi-polling CSMA-like random access mechanism operates in CFP. Each STA reserve channel access TXOPs from AP and AP schedules the transmission and disseminates this schedule through resource allocation message (RAL), in original SCCA the order of STAs to access channel is determined by different time slots each STA has to defer, however, a later proposal [6] use number of specific frames received to control the deferral. Once every STA receives the broadcast RAL message, each STA will start backoff, until the desirable deferral time slots are met before it can access the channel. The AP will terminate the CFP using CF-End packet.

Unlike the current multi-polling mechanism that depends on time unit or time slots for deferring, MERL's proposal uses the number of special type of frames (ACK/Restart frame) sent by AP to control the channel access of the STAs in multi-polling environment. Each STA can only transmit when it receives the exact number of special frames as indicated by AP in the multi-polling frame. Only AP can send out the special frame thus hidden terminal problems are avoided. AP will send piggybacked Restart with ACK or BlockACK when it is the intended recipient, or send Restart when it is not the intended recipient or the polled STA does not start transmission at the scheduled time. [6] has the detail information about this mechanism. This scheme allows STAs to defer its access to the channel without wasting too much channel resource.

3. Description and Explanation

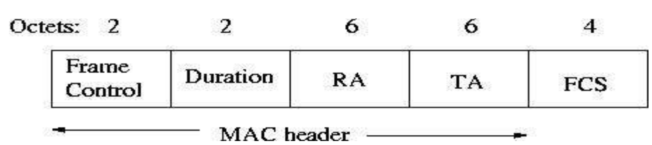
3.1 Basic Idea

From legacy 802.11 standard, the STAs will perform both PHY and MAC carrier sensing during CP. STAs will set their NAV according to the duration field of RTS/CTS/DATA/ACK frames. In CFP, during CFP all STAs in a BSS set up the NAV to CFPMaxDuration, and they can only transmit if polled by the AP. This mechanism has the following deficiencies: first, in CFP the NAV is set to CFPMaxDuration, so although STAs may hear RTS/CTS/DATA/ACK frames transmitted by STAs of the overlapping BSS, if the duration in those frames are less than CFPMaxDuration, the NAV counter will not be updated. Hence, it is not possible for the STA to be aware of the other transmission going on in the other BSS through NAV, when the STA is polled, it will reply and therefore may interfere the transmission going on the other BSS. In the proposed solution, the rules for transmission are changed to that during CFP, STA will not set NAV to CFPMaxDuration and the STA will not transmit unless it is polled and the NAV is 0, accordingly, we will modify the schemes related the NAV setup.

In order to differentiate the frames received from STAs (APs) that belongs to the same BSS or from overlapping BSS and record the corresponding durations, we propose two network allocation vectors, SBNAV and OBNAV.

3.2 Self-BSS Network Allocation Vector (SBNAV)

The proposed SBNAV is and works same as the original NAV, every time a STA hear a RTS/CTS/ACK packet that is not addressed to it, it will update the SBNAV (SBNAV is only updated when the duration field of the received frame is longer than current NAV). Figure 5 and 6 depict the frame format of RTS and CTS/ACK frame respectively. Notice that since RTS/CTS/ACK frame doesn't contain information about BSS id, the duration in those frames will be used to set SBNAV, although some of them are from overlapping BSS.



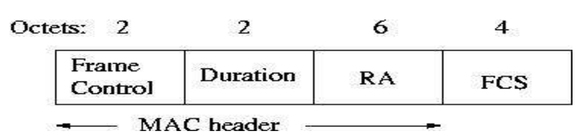


Figure 5: Frame format of RTS

Figure 6: Frame format of CTS/ACK

3.3 Overlapping Network Allocation Vector (OBNAV)

When a STA hears RAL from an overlapping BSS, it will set OBNAV to *infinite,* the OBNAV will be reset to zero when it hears the CF-End for the corresponding BSS or the overlapping BSS timeout is reached. The STA should have a counter to record how many RAL from overlapping BSSs it has heard and the OBNAV can only be reset when it has received the corresponding number of CF-Ends and/or timeouts. Figure 7 shows an example of OBNAV setting in a multiple overlapping BSSs scenario.

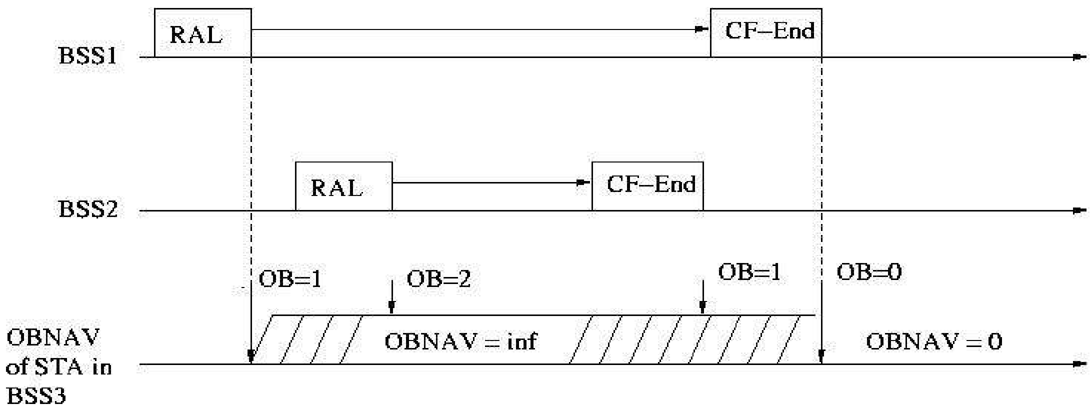


Figure 7: An example of OBNAV in multiple overlapping BSSs scenario

Although the RTS/CTS from overlapping BSSs are treated as SBNAV, frame header of DATA frame may contain BSSID that can be understood by the STA, so STA will set OBNAV according to the duration field of DATA frame.

3.4 Modified NAV

In this proposal, STAs still follow the rule of NAV --- STAs will not access channel unless the NAV is zero in both CFP and CP. Compared to the legacy NAV, which in CFP STA will transmit when polled no matter the value of current NAV, the rule of NAV in the proposal is more straightforward and consistent for CFP and CP. Moreover, notice that in this proposal the NAV is redefined to be either SBNAV or OBNAV, whichever is bigger, the redefinition maintains good backward compatibility for legacy STAs, to which the SBNAV and OBNAV are transparent and reduce the complexity of modification.

3.5 Modification for current standard/802.11n proposal

In order to make the proposal work, one more control type should be introduced to current IEEE 802.11 standard, the RAL frame. In MERL's previous SCCA proposal, RAL is defined to be management frame with subtype action, however, since all the other polling frames (PS-Poll, CF-Poll) are either control or data frames, we feel it is more appropriate for RAL to be a control frame. The modified valid type and subtype combinations are shown in Table 1.

Type Value b3 b2	***Type Description***	***Subtype Value*** b7 b6 b5 b4	***Subtype Description***
0 1	Control	0 0 0 0 – 0 0 1 1	Reserved
0 1	Control	0 1 0 0	RAL
0 1	Control	0 1 0 1	ACK/Restart
0 1	Control	0 1 1 0	BlockACK/Restart
0 1	Control	0 1 1 1	Restart

Table 1: Modified valid type and subtype combinations

The reclassification of RAL allows STAs in other BSS to recognize it and set the corresponding OBNAV. The frame format of redefined RAL is shown in Figure 8. The length field represents the number of multi-schedule elements that follows. The structure of multi-schedule element is same as MERL's SCCA proposal and is shown in Figure 9. The sequence index value (SIV) component is the number of ACK/Restart frames the STA should receive before it can access the channel. This value essentially determines order of STAs to access the channel. The association id (AID) field contains the AID of the STA to which this reservation allocation belongs.

Octets:	2	2	6	6	2	14		14	4
	Frame Control	Duration	BSSID	TA	Length	Multi–Schedule Element 1	. . .	Multi–Schedule Element n	FCS
	← MAC header →								

Figure 8: Frame format of redefined RAL

Octets:	2	2	2	4	2	2
	AID	Schedule Info	SIV	Service Interval	TXOP	Specification Interval

Figure 9: Format of multi-schedule element subfield

The schedule info subfield, which is not depicted here, is identical to that defined by IEEE 802.11e. The AID, along with the TSID and direction field in the schedule info subfield, can uniquely identify a flow. All other fields and subfields inherit the definition of IEEE 802.11e and MERL's SCCA proposal.

Notice that this reclassification and redefinition of RAL are the only modifications needed for current 802.11n proposal.

4. Working Examples of Proposed Mechanism

In this section we will illustrate how the proposed mechanism works under different network configurations, we will use situations A, B and C to represent different configurations. For each configuration, we will study two scenarios, in scenario1 one BSS operates in CFP and the other BSS operates in CP. From now on, for scenario1, it is always assumed that BSS1 is the BSS operates in CFP and BSS2 operates in CP. In scenario 2, both BSSs operate in CFP. For the scenario that both BSSs operating in CP, since it is contention-based channel access, the overlapping BSSs scenario is analogous to a large scale independent BSS, it is similar to IBSS analysis and will not be studied here.

4.1 Situation A

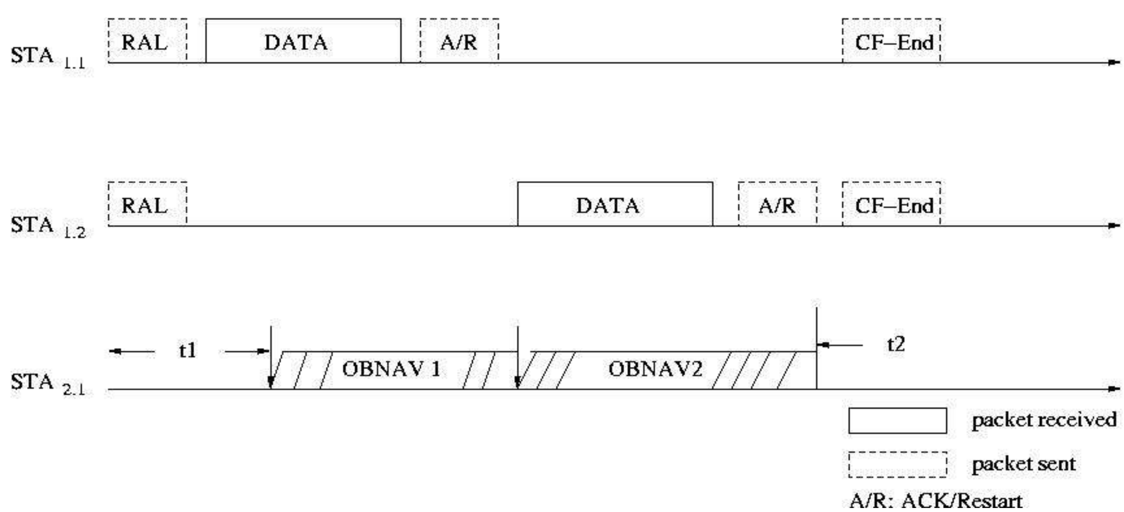


Figure 10: Example of situation A, scenario 1

Figure 10 depicts an example of situation A, scenario 1. In this scenario, since $STA_{2.1}$ can not hear the RAL from AP_1, it will not be able to set OBNAV to inf hence it is not guaranteed that $STA_{2.1}$ will not interfere BSS_1's SCCA transmission. In this specific example, since $STA_{2.1}$ is able to hear transmissions from $STA_{1.1}$ and $STA_{1.2}$, it can set its OBNAV according to the DATA frame transmitted by $STA_{1.1}$ and $STA_{1.2}$ and won't interfere those transmissions. On the other hand, if $STA_{2.1}$ transmits ahead of $STA_{1.1}$, (during t1)

$STA_{1.1}$ and $STA_{1.2}$ will be able to set their own OBNAV and don' t response to the RAL, or, AP_1's RAL will collide with $STA_{2.1}$'s transmission, in both cases, (not shown in Figure 10), $STA_{1.1}$ and $STA_{1.2}$ will not transmit, therefore collisions are still avoided and AP_1 will terminate CFP using CF-End [6]. If $STA_{2.1}$ transmits during t2, the CF-End frame will be collided by $STA_{2.1}$'s transmission. However, if there is a $STA_{1.3}$ that is outside the transmission range of $STA_{2.1}$, its communication with AP1 will not be affected and actually simultaneous communication in BSS_1 and BSS_2 is possible.

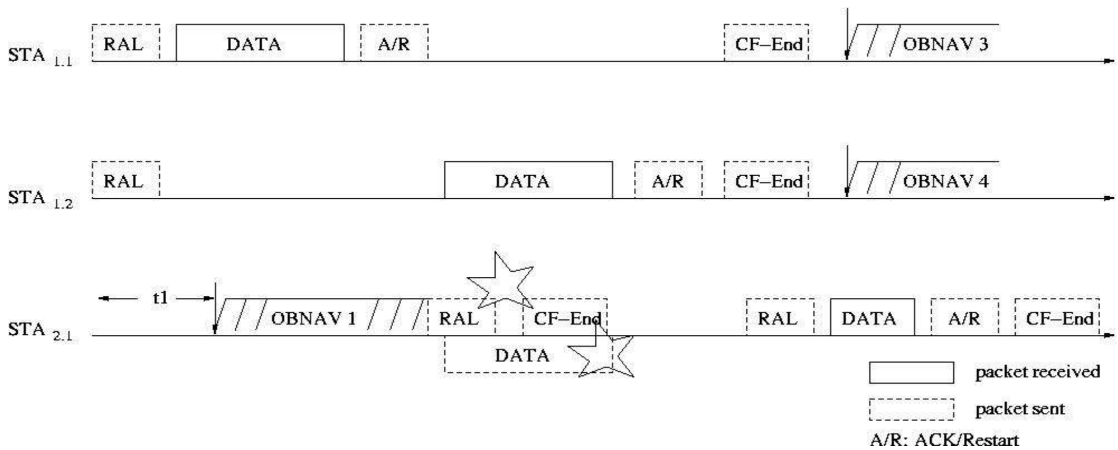


Figure 11: Example of situation A, scenario 2

Figure 11 depicts an example of situation A, scenario2, where both BSSs operate in CFP. In Figure 11, AP_1 first sends out RAL, $STA_{2.1}$ will set its OBNAV according to the duration field from the DATA frame it received from $STA_{1.1}$; AP2 then sends out RAL, however, since $STA_{2.1}$ is also in $STA_{1.1}$ and $STA_{1.2}$'s transmission range, at $STA_{2.1}$, RAL will collide with DATA frame from $STA_{1.2}$, therefore $STA_{2.1}$ will not respond to RAL and after a short period, AP_2 detects this event and sends out CF-End. When AP_2 sends out RAL again, $STA_{1.1}$ and $STA_{1.2}$ will set their OBNAVs based on the DATA frame sent by $STA_{2.1}$. By this means, the potential collisions between STAs from different BSSs are avoided and the channel is shared between two BSSs and the waste of bandwidth is reduced.

4.2 Situation B

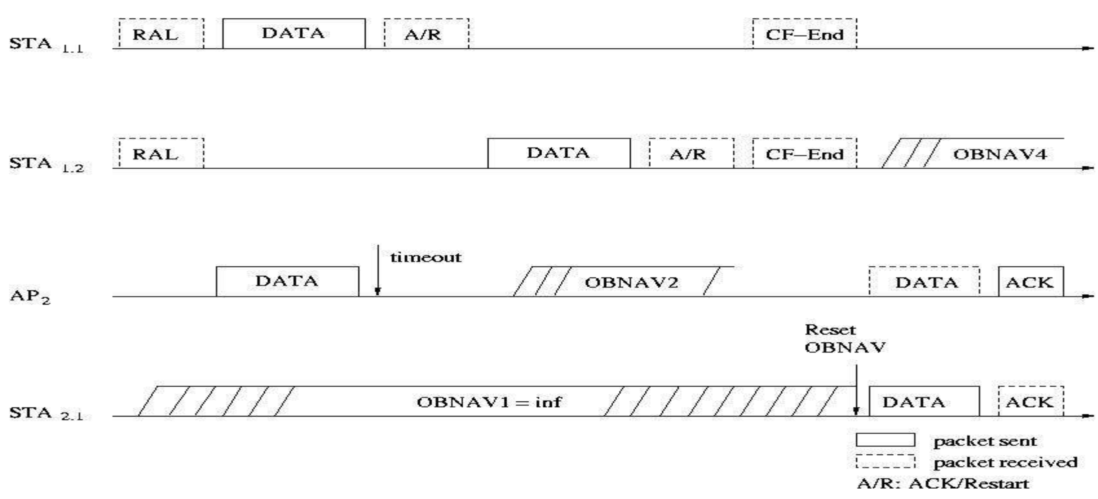


Figure 12: An example of Situation B, scenario1

Figure 12 depicts an example of situation B, scenario1. In situation B, $STA_{2.1}$ is in AP_1's transmission range, while $STA_{1.2}$ is in AP_2's transmission range. When AP_1 sends RAL, $STA_{2.1}$ hears the RAL frame and sets its OBNAV to *infinity*. During this period, $STA_{2.1}$ will not compete for the channel and will not response to any polling (when BSS_2 is in CFP), even if AP_1 transmits DATA to it during this period, $STA_{2.1}$ will not acknowledge it. Thus the collisions with transmissions in BSS_1 are avoided. On the other hand, since AP_2 cannot hear AP_1 but can hear $STA_{1.1}$, so AP_2 will set its OBNAV according to the duration field in the DATA frame sent by $STA_{1.1}$. When CFP in BSS_1 is complete, AP_1 sends out CF-End, and $STA_{2.1}$ then reset its OBNAV to 0, thus AP_2 and $STA_{2.1}$ can exchange packets.

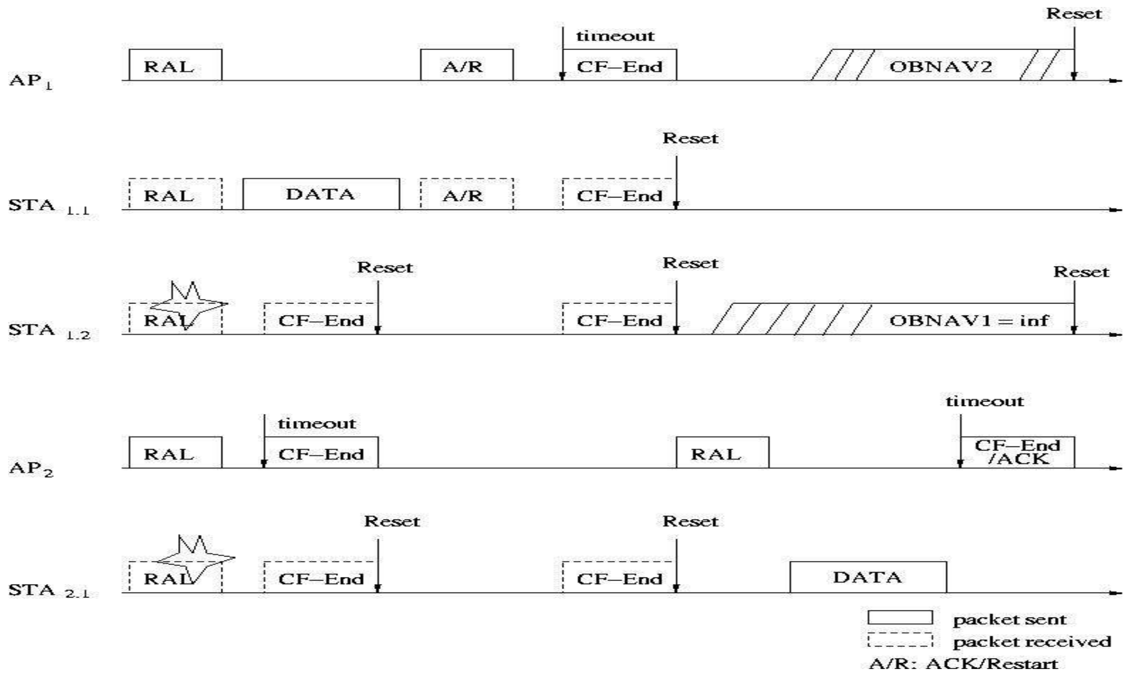


Figure 13: An example of situation B, scenario 2

Figure 13 depicts an example of situation B, scenario 2. At beginning, both APs send RAL, although APs can not hear each other, the two RALs will collide at $STA_{1.2}$ and $STA_{2.1}$, whereas $STA_{1.1}$ can hear AP_1's RAL correctly and response to the polling, $STA_{1.2}$ and $STA_{2.1}$ will not response to RAL. Thus first AP_2 will send CF-End and then AP_1 will send CF-End. Upon receiving CF-Ends, if there is pending RALs, the STA will not reset, however, if there is no pending RALs, STA will just reset OBNAV to 0. For this scenario, $STA_{1.2}$ and $STA_{2.1}$ will receive multiple CF-Ends but the corresponding RALs are collided, hence there is no pending RAL and OBNAV is reset to 0. Then AP_2 will send RAL again, this time both $STA_{1.2}$ and $STA_{2.1}$ will hear the RAL and $STA_{2.1}$ will set its OBNAV to *infinity* and $STA_{1.2}$ will response to the RAL. When $STA_{1.2}$ sends DATA to AP_2, AP_1 will hear the DATA frame and set its OBNAV according to the duration field in the DATA frame. $STA_{2.1}$ will reset its OBNAV when it hears the CF-End/ACK frame from AP_2.

4.3 Situation C

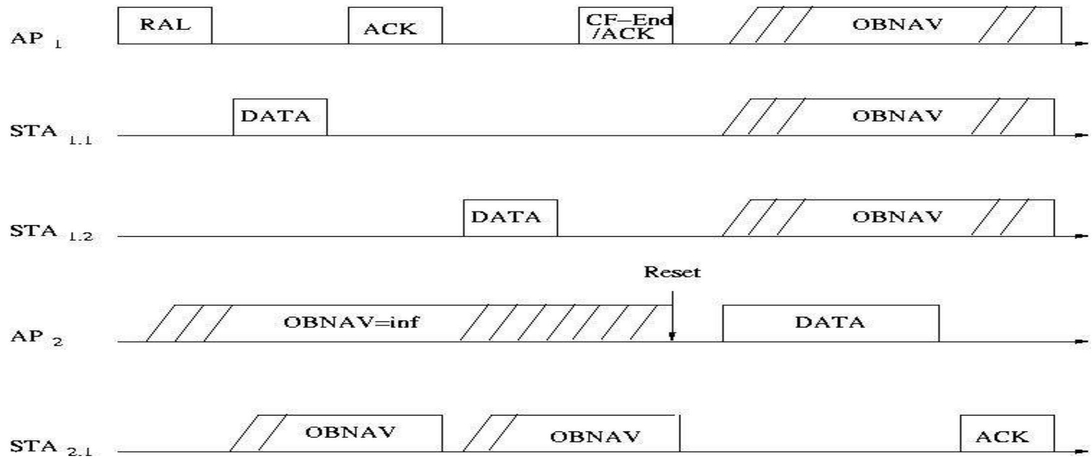


Figure 14: An example of situation C, scenario 1

Figure 14 and Figure 15 depict two examples of situation C, scenario1 and scenario 2 respectively. In situation C, AP_2, $STA_{1.2}$ and $STA_{1.1}$ can hear all STAs and AP in the network, while AP_1 can hear all STAs and AP except $STA_{2.1}$, similarly, $STA_{2.1}$ can hear all STAs and AP except AP_1. For scenario1, BSS1 is in CFP and BSS2 is in CP, AP_2 and $STA_{2.1}$ have to wait AIFS to access channel, while AP_1 only need to wait PIFS to access channel, when AP_2 hears the RAL from AP_1, it will set its OBNAV to *infinity*; although $STA_{2.1}$ can not hear RAL from AP_1, it can hear the DATA frames send by both $STA_{1.1}$ and $STA_{1.2}$, hence it is able to set its OBNAV according to the duration field of the DATA frames. Upon receiving the CF-End/ACK frame from AP_1, AP_2 will reset its OBNAV. When AP_2 accesses the channel, all STAs from BSS1 will hear the DATA frame and set their OBNAVs accordingly.

For scenario2, both BSSs are operating in CFP. In this case, given that APs can hear each other, when AP1 sends out RAL, AP2 will set its OBNAV to infinity, same as scenario1, STA2.1 will set its OBNAV according to the DATA frames it hears from STA1.1 and STA1.2. When AP2 sends out RAL, all STAs and AP1 will set their OBNAVs to *infinity* and will reset the OBNAV upon receiving the CF-End/ACK frame.

5. Backward Compatibility

The proposed OBNAV mechanism is built on top of the original NAV mechanism, given the original NAV is redefined as SBNAV, the new NAV is defined as the maximal value of OBNAV and SBNAV. At the network level, all the STAs follow the original rules of NAV. Hence the proposed mechanism is fully backward compatible with the legacy STAs.

6. Implementation Issues

The proposed mechanism can be implemented by software. The pseudo code for this mechanism is shown in Figure 16. For the NAV scheme, two more counters are needed, OBNAV and SBNAV, a simple compare mechanism to determine the NAV. A third counter is needed for the STA to store the number of RALs received from overlapping BSSs. During CFP, unlike in legacy 802.11, STA will not set their OBNAV to CFPMaxDuration; moreover, STA will not transmit either unless being polled. Note that the infinite OBNAV can only be reset when same number of CF-Ends are received or overlapping BSS timeouts are met. The timeout is introduced to deal with the cases that STA has successfully received RAL from overlapping BSS but is not able to receive the CF-End due the collision or bad channel. The timeout value for each RAL is set to be the maximum duration of CFP--- CFPMaxDuration. Hence for *n* overlapping BSSs, the actual timeout value will be n ×CFPMaxDuration.

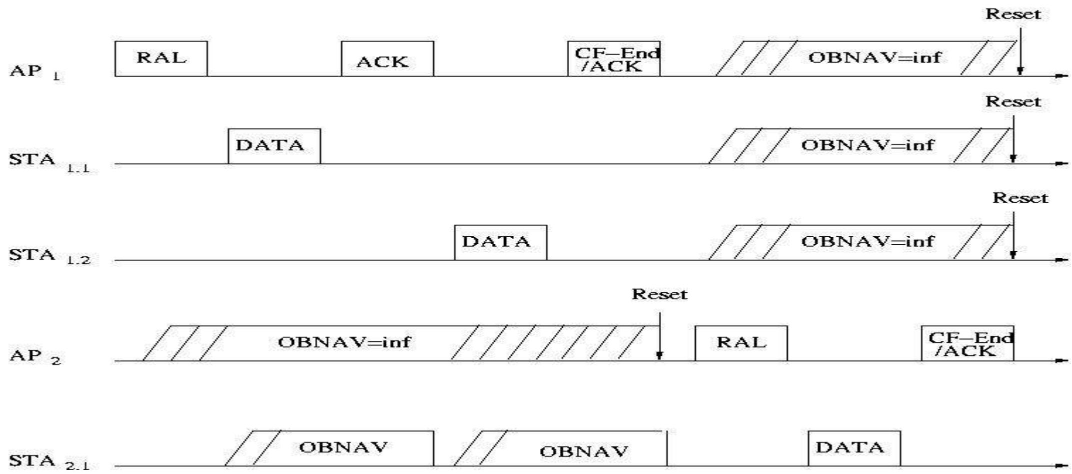


Figure 15: An example of situation C, scenario 2

7. Conclusion

A new mechanism to overcome the overlapping BSS problem is proposed. The proposed mechanism employs a two–level carrier sensing to for both self-BSS and overlapping BSS. A new network allocation vector is introduced to account for the necessary deferrals from overlapping BSSs, the original NAV is redefined as SBNAV. The overall NAV is defined as the maximum value of SBNAV and OBNAV. The proposed mechanism is capable of scheduling channel access among overlapping BSSs and efficient channel usage and reduce the channel waste due to collisions.

```
Listen to the channel,
switch (packet received)
case RTS/CTS/ACK:
   set SBNAV according to the duration field
case DATA:
   if comes from self BSS
     set SBNAV according to the duration field
   else
     set OBNAV according to the duration field
   end
case RAL:
    if comes from self BSS
      perform CFP operation
    else
      set OBNAV to infinite, increase PendingRAL counter
    end
case CF-End/ACK or CF-End:
    if comes form self BSS
     perform CFP operation
    else
     decrement PendingRAL counter
     if (PendingRAL ==0) reset OBNAV end
    end
```

Figure 16: Pseudo code for proposed mechanism

Reference

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3. Gerard G. Cervello and Sunghyun Choi, "Collision Avoidance in Overlapping BSSs of 802.11 WLAN", IEEE 802.11-00/194, September 2000
4. Stefan Mangold, Jorg Habetha, Sunghyun Choi and Chiu Ngo, "Co-existence and interworking of IEEE 802.11a and ETSI BRAN HiperLAN/2 in multi-hop scenarios", IEEE workshop on wireless local area networks, Sep. 2001
5. MERL's proposal on SCCA
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