IEEE P802.11  
Wireless LANs

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| --- | --- | --- | --- | --- |
| CR for Power Save of AP MLD | | | | |
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Abstract

This submission proposes resolutions for following CIDs received for TGbe (CC36):

5064, 6929

***TGbe Editor: Please note, the baseline for this document is REVme D1.0 and TGbe D1.5***

Revisions:

* Rev 0: Initial version
* Rev 1: Editorial modifications.
* Rev 2-5: Add the modifications based on received comments
* Rev 6: Make some changes (in green) on the text based on received comments.
* Rev 7: Make some changes (in green) on the discussion part

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **CID** | **Commenter** | **Section** | **Pg/Ln** | **Comment** | **Proposed Change** | **Resolution** |
| 5064 | Gaurang Naik | 35.3.17.1 | 284.24 | An NSTR soft AP is a mobile device and may have considerations similar to a non-AP MLD such as power save. The spec currently does not have a mechanism to signal the unavailability of the non-primary link for a soft AP MLD. | Define a mechanism by which an NSTR soft AP MLD can signal the unavailability of the nonprimary link | Revised  Agree with the commenter in principle. Although the commenter proposed to define a power save mechanism for the NSTR mobile AP MLD, we also need to consider the power save issue for the regular AP MLD.  Considering the following cases:   * In some use case, the non-AP MLD wants to enhance its throughput or improve the delay by using the multi-link for delivery. Hence, we should allow the non-AP MLD to wake up the AP in the doze state in some case. So we define a power save mode. * In some use case, e.g. the AP maintenance, regulatory reasons or the NSTR mobile AP MLD being in a low-power level, the affiliated AP in the doze state doesn’t allow the non-AP MLD to wake up it. So we define a sleep mode.   Hence, the proposed resolution can address the above different use cases.  TGbe editor, please make changes as shown in doc 11-21/0356r7 tagged 5064 |
| 6929 | Ryuichi Hirata | 35.3.17.1 | 284.20 | Soft AP MLD is typically battery powered, therefore power save mechanism for soft AP MLD should be defined. | Define power save mechanism for soft AP MLD. | Revised  TGbe editor, please make changes as shown in doc 11-21/0356r7 tagged 5064 |

**Q&A.**

Q1. Why do we need to define a power save mechanism for the AP MLD?

1. Before 11be, the power save operation is only considered for the STA side. The reason is, for the single-link AP, we cannot allow it to enter the doze state and do the power save, rather than we cannot define power states (awake state and doze state) for the AP. But with the multi-link being standardized, it makes the power save of the AP MLD feasible.

In addition, driven by targets to combat/limit climate change, European regulation on ‘per 24 hour’ power consumption envelopes may lead the way (Please refer to doc. 22/0059r0). For instance, in the near future, an AP power save function will be mandatory in all products in the European market.

Hence, we should consider the power save issue for the AP MLD, not just for the NSTR mobile AP MLD.

Q2. Why do I think it is not a good way to use the term “Link Unavailability” or “Link Disablement” as the power save operation for the AP MLD?

1. If we go through the current 802.11 protocol, we can see that all the power save mechanisms (except the OMI) rely on the transition between the awake state and the doze state and try to reduce the time in the awake state as much as possible.

To design a power save mechanism for the AP MLD, I strongly suggest to follow the current terms (awake state and doze state) and design a power save mechanism for the AP MLD on top of it. I don’t see the benefit to define a new concept to do the power save for the AP MLD! If we choose to use the term “Link Unavailability” or “Link Disablement”, then a follow-up question is what’s the power state when a link is unavailable or disabled? It’s more informal and more straightforward to use the power states to describe the power save for the AP MLD, rather than defining a new concept!

Furthermore, if we go in that way, we need to make many changes on the current draft text. I will give some examples in the following.

Example 1. The term “Link Disablement” is defined based on the TID-to-link mapping negotiation between the AP MLD and the association non-AP MLD. But for an unassociated non-AP MLD, there is no so-called link disablement or enablement.

Example 2. Currently, the TID-to-link mapping negotiation is optional. That means, if any non-AP MLD doesn’t support the TID-to-link mapping negotiation and set up this link which may be disabled later, then the AP MLD cannot use the TID-to-link mapping to signal the link disablement.

Example 3. Based on the below definition of the link disablement, if the link is disabled for all associated non-AP MLDs, whether the group addressed frames can be sent? It’s not clear.

*“(#5365)(#6281)If a link is disabled for a non-AP MLD, it shall not be used for individually addressed frame exchange between the corresponding STA and AP of the non-AP MLD and AP MLD, including Management frames.”*

Q3. Why do we need to define a wakeup mechanism?

1. When an affiliated AP is operating in the power save mode, the wakeup procedure is illustrated as the below figure, which is similar to the existing U-APSD. The main differences between the proposed U-APSD and the existing U-APSD are listed as follows:

* The AP (affiliated with an AP MLD) is also operating in the power save mode.
* The trigger from the STA side (i.e. wakeup request) is sent on a link on which the AP (affiliated with that AP MLD) is operating in the active mode.



Note. For the proposed power save mode, the AP MLD cannot allow all affiliated APs to operate in the power save mode.

The signaling related to the power save of the AP MLD is only known to the non-AP MLD. But for the non-AP MLD characterized by the multi-link capability, it may still want to use the multi-link for delivery at some time. And the AP MLD has no way to predict this time point. Hence, when the AP affiliated with an AP MLD is operating in the power save mode, a wake up mechanism is proposed to balance the power save of the AP MLD and the instant throughput needs of the non-AP MLD. Thus, the proposed resolution will not degrade the transmission performance of the associated non-AP MLDs while reducing the power consumption of the AP MLD as much as possible. If we don’t define a corresponding wake-up mechanism, how does the non-AP MLD show its advantage of the multiple links?

In the following, we give the following examples.

Example 1.

In the home scenario, normally there are only several associated non-AP MLDs. Assuming that the AP MLD has three links, link 1, link 2 and link 3. When the traffic load is relatively low, the AP MLD can let one or two links operate in the power save mode. If any non-AP MLD wants to use the multi-link to upload a large file, then it can send a wakeup request to wake up the affiliated AP in the power save mode with the doze state. And when the More Data subfield of the PPDU transmitted by this non-AP MLD is set to 0, then the affiliated AP can transition from the awake state to the doze state.

Example 2.

In the home scenario, normally there are only several associated non-AP MLDs. Assuming that the AP MLD has three links, link 1, link 2 and link 3. When the traffic load is relatively low, the AP MLD can let one or two links operate in the power save mode. If any non-AP MLD wants to use the multi-link to attend a HD video teleconference, then it can send a wakeup request to wake up the affiliated AP in the power save mode with the doze state. The affiliated AP in the power save mode may enter the active mode to provide a good user experience.

Example 3.

For the NSTR mobile AP MLD, considering that it is typically battery powered and the non-AP MLD cannot initiate a PPDU transmission alone on the non-primary link, it is better to let the affiliated AP in the non-primary link operates in the power save mode. Only when the non-AP MLD wants to use the multi-link for delivery, then it can send a wakeup request to wake up the AP operating on the non-primary link.

Example 4.

In the future, the AP MLD may integrate the 60 GHz chip set as a link. As we known, the 60 GHz link may be used for the AR/VR application and it has a high power consumption. A typical use case is, the AP operating on the 60 GHz link is in the power save mode with the doze state. Only when the non-AP MLD starts the AR/VR application and sends a wakeup request to the AP operating on the 60 GHz link. Then it can transition from the doze state to the awake state or enter the active mode.

*TGbe editor: Change the following subclause as follows: (#5064)*

**9.4.2.170 Reduced Neighbor Report element**

**9.4.2.170.2 Neighbor AP Information field**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | B0 B7 | B8 B11 | B12 B19 | B20 B21 | B22 B23 |
|  | MLD ID | Link ID | BSS Parameters Change Count | Power Management Mode | Reserved |
| Bits: | 8 | 8 | 4 | 2 | 2 |
| **Figure 9-709c MLD parameters subfield format** | | | | | |

The Power Management Mode subfield indicates the power management mode of the corresponding reported AP that is affiliated with an AP MLD and its encoding is defined in Table 9-xyz (Power Management Mode subfield values).

**Table 9-xyz—Power Management Mode subfield values**

|  |  |  |
| --- | --- | --- |
| Values | Meaning | Description |
| 00 | Active mode | In this mode, the corresponding AP is always in the awake state. |
| 01 | Reserved |  |
| 10 | Power save mode | In this mode, the AP is allowed to transition between the awake state and the doze state. The AP operates in the doze state by default. The AP in the power save mode will transition from the doze state to the awake state if one of the following conditions is met:   * It receives a wakeup request. * A TWT SP starts. * There is one or more buffered BUs at this AP and it has been signalled through the Multi-link Traffic element carried within the Beacon frame sent by another AP affiliated with the same AP MLD. |
| 11 | Sleep mode | In this mode, the corresponding AP is always in the doze state. And The non-AP MLD cannot send a wakeup request to this AP through its affiliated STA. |

**9.4.2.312 Multi-link Control field of the Basic Multi-link element**

***TGbe editor: Update the following Figure 9-1002d (Presence Bitmap subfield of the Basic Multi-Link element format) as follows:***

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | B0 | B1 | B2 | B3 | B4 | B5 | B6 B11 |
|  | Link ID Info Present | BSS  Parameters Change Count Present | Medium Synchronization Delay Information Present | EML  Capabilities Present | MLD  Capabilities Present | Power Management Information Present | Reserved |
| Bits: | 1 | 1 | 1 | 1 | 1 | 1 | 6 |
| **Figure 9-1002d—****Presence Bitmap subfield of the Basic Multi-Link element format** | | | | | | | |

***TGbe editor: Add the following at the end of this subclause as follows:***

The Power Management Information Present subfield is set to 1 if the Power Management Information subfield is present in the Common Info field. Otherwise, the Power Management Information Present subfield is set to 0.

**9.4.2.312.2.2 Multi-link Control field of the Basic Multi-link element**

***TGbe editor: Update the following Figure 9-1002h (Common Info field of the Basic Multi-Link element format) as follows:***

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Common Info Length | MLD MAC  Address | Link ID Info | BSS  Parameters Change Count | Medium Synchronization Delay Information | EML  Capabilities | MLD  Capabilities | Power Management Information |
| Octets: | 1 | 6 | 0 or 1 | 0 or 1 | 0 or 2 | 0 or 2 | 0 or 2 | 0 or 2 |
| **Figure 9-1002h— Common Info field of the Basic Multi-Link element format** | | | | | | | | |

***TGbe editor: Add the following at the end of this subclause as follows:***

The format of the Power Management Information subfield is defined in figure 9-1002ha (Power Management subfield format).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | B0 B1 | B2 B3 | B4 B7 | B8 B15 |
|  | Power Management Mode | Wakeup Delay | Reserved | Mode Switch Count |
| Bits: | 2 | 2 | 4 | 8 |
| **Figure 9-1002ha—Power Management Mode subfield format** | | | | |

The Power Management Mode subfield indicates the power management mode of the corresponding ~~reported~~ reporting AP that is affiliated with an AP MLD and its encoding is defined in Table 9-xyz (Power Management Mode subfield values).

The Wakeup Delay subfield indicates the transition delay time needed by an AP that is affiliated with an AP MLD to switch from the doze state to the awake state. The Wakeup Delay subfield includes 2 bits and is set as define in Table 9-xxx (Encoding of the Wakeup Delay subfield).

Table 9-xxx Encoding of the Wakeup Delay subfield

|  |  |
| --- | --- |
| Wakeup Delay subfield value | Wakeup delay |
| 0 | 0 us |
| 1 | 32 us |
| 2 | 64 us |
| 3 | 128 us |

The Mode Switch Count subfield indicates the number of TBTTs after which the power management mode of the reporting AP will change.

**9.4.2.312.2.3 Link Info field of the Basic Multi-link element**

***TGbe editor: Update the following Figure 9-1002k (STA control field format) as follows:***

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | B0 B3 | B4 | B5 | B6 | B7 | B8 | B9 | B10 | B11 | B12 B15 |
|  | Link ID | Complete Profile | STA MAC  Address Present | Beacon Interval Present | DTIM Info Present | NSTR  Link Pair Present | NSTR  Bitmap Size | BSS Parameters Change Count Present | Power Management Information Present | Reserved |
| Bits: | 4 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
| **Figure 9-1002n— STA Control field format** | | | | | | | | | | |

***TGbe editor: Add the following paragraph of this subclause as follows:***

The Power Management Information Present subfield is set to 1 if the Power Management Information subfield is present in the STA Info field. Otherwise, the Power Management Information Present subfield is set to 0.

***TGbe editor: Update the following Figure 9-1002l (STA Info field format) as follows:***

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | STA Info Length | STA MAC  Address | Beacon Interval | DTIM Info | NSTR  Indication Bitmap | BSS Parameters Change Count | Power Management Information |
| Octets: | 1 | 0 or 6 | 0 or 2 | 0 or 2 | 0 or 1 or 2 | 0 or 1 | 0 or 2 |

**Figure 9-1002o— STA Info field format**

***TGbe editor: Add the following paragraph of this subclause as follows:***

The format of the Power Management Information subfield is defined in section 9.4.2.312.2.2, figure 9-1002ha (Power Management Information subfield format) and applies to the AP corresponding to the Per-STA Profile subelement.

Note – In case the Per-STA Profile subelement corresponds the AP affiliated with a NSTR mobile AP MLD and that is operating on the non-primary link, the Mode Switch Count subfield indicates the number of TBTTs corresponding to the primary link.

*TGbe editor: Change the following subclause as follows: (#5064)*

**9.2.4.7.10 AAR Control**

The Control Information subfield in an AAR Control subfield contains information related to the procedure that allows an AP affiliated with an AP MLD to assist a non-AP STA affiliated with a non-AP MLD that belongs (#7555)an NSTR link pair to recover its medium synchronization (35.3.16.8.2 (AP assisted medium synchronization recovery procedure)).

It is also used to wake up the corresponding AP affiliated with an AP MLD and that is operating in the power save mode (35.3.13 Power save for AP MLD).

The format of this subfield is shown in Figure 9-33c (Control Information subfield format in an AAR Con- trol subfield).

|  |  |  |  |
| --- | --- | --- | --- |
|  | B0 B7 | B8 | B9 B11 |
|  | Assisted Link ID Bitmap | Type | Reserved |
| Bits: | 16 | 1 | 3 |
| **Figure 9-33c Control Information subfield format in an AAR Control subfield** | | | |

If the Type subfield is set to 0, the Assisted AP Link ID Bitmap subfield indicates the link identifier(s) of an AP affiliated with an AP MLD that is solicited to transmit a Trigger frame to a non-AP STA affiliated with a non-AP MLD that belongs to (#7555)an NSTR link pair after a frame that contains AAR Control subfield sent by another non- AP STA affiliated with the same non-AP MLD to its associated AP affiliated with the same AP MLD. If the Type subfield is set to 1, the Assisted AP Link ID bitmap subfield indicates the link identifier(s) of an AP affiliated with an AP MLD that operating in the power save mode is requested to wake up after a frame that contains AAR Control subfield sent by another non-AP STA affiliated with the same non-AP MLD to its associated AP affiliated with the same AP MLD. A value of 1 in bit position i of the Assisted AP Link ID Bitmap subfield means that the link ID i is the link identifier of the solicited AP affiliated with the AP MLD. A value of 0 in bit position i of the Assisted AP Link ID Bitmap subfield means that the link ID i is not the link identifier of the solicited AP affiliated with the AP MLD.

The Type subfield specifies the function of the AAR Control subfield. The Type subfield is set to 0 if the AAR Control subfield is used to solicit to transmit a Trigger frame and set to 1 if the AAR Control subfield is used to wake up the corresponding APs for the frame exchange.*TGbe editor: Add the following paragraph in the following subclause as follows: (#5064)*

**35.3.4 Discovery of an AP MLD**

**35.3.4.1 AP Behavior**

If an AP affiliated with an AP MLD is operating in the power save mode or the sleep mode, the TBTT Information Field Type subfield and the TBTT Information Length subfield of the TBTT Information field corresponding to this AP shall be set to 1 and 3, respectively.

*TGbe editor: Add the following subclause as follows: (#5064)*

**35.3.X AP MLD Power save(#5064)**

An AP MLD shall notify the power management mode of an affiliated AP by using the corresponding Power Management Mode subfield within the Reduced Neighbor Report element and/or the Basic Multi-link element included in the Beacon or Probe Response frames transmitted by any of the APs affiliated with the AP MLD.

Note 1 – To optimize the network performance, the AP MLD may try to manage the non-MLD devices. For example, the AP MLD may ~~prohibit the non-MLD STAs to associate with the specified affiliated AP by advertising a new BSS membership selector or~~ use the BTM in advance before the affiliated AP enters the power save mode or the sleep mode.

Note 2 – The AP MLD shall not allow all its affiliated APs to operate in the power save mode or the sleep mode simultaneously.

An AP affiliated with an AP MLD may enter the active mode by setting the Power Management Mode subfield to 00 within the Reduced Neighbor Report element and/or the basic Multi-link element carried in the Beacon and Probe response frames. If the AP affiliated with an AP MLD is operating in the active mode, it always remains in the awake state.

An AP affiliated with an AP MLD may enter the power save mode by setting the Power Management Mode subfield in the Reduced Neighbor Report element and/or the Basic Multi-link element to 10.

An AP affiliated with an AP MLD may enter the sleep mode by setting the Power Management Mode subfield in the Reduced Neighbor Report element and/or the Basic Multi-link element to 11. If an AP affiliated with an AP MLD is operating in the sleep mode, it always remains in the doze state.

Note. The Power Management Mode indication through the RNR is mainly used for unassociated non-AP MLD which utilizes the RNR for the Discovery of the AP MLD and each of its affiliated APs to avoid sending Probe Request/(Re)Association Request frames to the reported AP in the power save mode or the sleep mode.

If an AP affiliated with an AP MLD is operating in the power save mode or the sleep mode, the TBTT Information Field Type subfield and the TBTT Information Length subfield of the TBTT Information field corresponding to this AP shall be set to 1 and 3, respectively.

An AP affiliated with an AP MLD that intends to enter the power save mode or the sleep mode shall start including the Power Management Information subfield for a duration that is greater than or equal to the maximum value of the DTIM interval corresponding to each of the APs affiliated with the same AP MLD.

Note 1 – Advertising the Power Management Information subfield for a duration that includes the DTIM beacon on another link makes it possible for a non-AP MLD that is monitoring only the other link and is in doze state to wake up only to receive the DTIM beacon on that link to get this notification.

Note 2 – The Mode Switch Count value shall be applied in reference to the most recent TBTT value corresponding to the affected AP and not to the reporting AP. But for the NSTR mobile AP MLD, the Mode Switch Count value shall be applied in reference to the most recent TBTT value corresponding to the reporting AP operating on the primary link.

When an AP affiliated with an AP MLD is operating in the power save mode, it shall advertise the corresponding Wakeup delay through the Wakeup Delay subfield of the Basic Multi-link element carried in the Beacon and Probe response frames.

When an affiliated AP is advertised in the power save mode, if a non-AP MLD wants to use the corresponding link for delivery, it shall send a PPDU carrying an AAR Control subfield with the Type subfield equal to 1 to wake up this AP through an affiliated STA and corresponding affiliated AP, respectively.

If an AP in the power save mode with the awake state and that is affiliated with an AP MLD shall not transmit the Beacon frame and Probe Response. The AP affiliated with an AP MLD and that is operating in the doze state is not able to transmit or receive any PPDU.

When an AP affiliated with an AP MLD that operates in the power save mode, all the existing TWT agreement on this link and TID-to-link mapping are still valid. The member STA of a TWT doesn’t need to send an extra wakeup request to wake up the corresponding AP in the power save mode when a TWT SP is started. And the corresponding AP and its member STAs which have set up the TWT agreement shall remain in the awake state during the corresponding TWT SP. After the TWT SP is ended, the corresponding AP and its member STAs transitions from the awake state to the doze state.

When an AP affiliated with an AP MLD transitions from the doze state to the awake state, it shall initialize the power management status of the STA affiliated with a non-AP MLD and who had sent a wakeup request as ~~the power save mode with the awake state or in~~ the active mode. On the other hand, it shall initialize the power management status of the STA affiliated with a non-AP MLD and who hadn’t sent a wakeup request as the power save mode with the doze state.

An affiliated AP that is operating in the power save mode shall enter the awake state within the wakeup delay after successfully receiving a PPDU carrying an AAR Control subfield with the Type subfield equal to 1. When an affiliated AP that is changing from the doze state to the awake state in order to transmit shall perform CCA until a frame is detected by which it can set its NAV, or until a period of time indicated by the NAVSyncDelay has transpired.

After an affiliated AP in the power save mode is waked up, it may switch back to the doze state if one of the following conditions is met:

* The channel has been idle for a given time period.
* Each non-AP MLD who previously sent a PPDU carrying an AAR Control subfield with the Type subfield equal to 1 to wake up this AP had already set the More Data subfield of the last PPDU to 0.

When an AP affiliated with an AP MLD is operating in the power save mode,

* All the existing TWT agreements on this link are still valid. Both the affiliated AP and corresponding affiliated STAs shall be awake in order to exchange frames during the TWT SP;
* All the TID-to-link mapping agreement are still valid.

When an AP affiliated with an AP MLD is operating in the sleep mode,

* All the existing TWT agreements on this link shall be suspended;
* All the TID-to-link mapping agreements are still valid ~~teardown and the default TID-to-link mapping is used~~.

After the AP affiliated with an AP MLD transitions from the sleep mode to the active mode or the power save mode, all the existing TWT agreements on this link shall be resumed.

* More Data subfield

~~The More Data subfield is used differently by a DMG, an S1G STA, and a non-DMG non-S1G STA(#464).~~

~~A non-DMG and non-S1G STA uses the More Data subfield to indicate to a STA in PS mode that more BUs are buffered for that STA at the AP. The More Data subfield is valid in individually addressed Data or Management frames transmitted by an AP to a STA in PS mode. The More Data subfield is set to 1 to indicate that at least one additional buffered BU is present for the same STA.~~

~~A STA affiliated with a non-AP MLD uses the More Data subfield to indicate to an AP that is affiliated with an AP MLD and operating in the power save mode that more BUs are buffered for that AP at that STA. The More Data subfield is valid only in individually addressed Data or Management frames transmitted by a STA affiliated with a non-AP MLD to an AP that is affiliated with an AP MLD and operating in the power save mode. The More Data subfield is set to 1 to indicate that at least one additional buffered BU is present for the AP that is affiliated with the AP MLD and operating in the power save mode.~~

~~(11ax)An AP optionally sets the More Data subfield to 1 in Ack frames sent to a non-DMG non-S1G non-HE STA and in Ack, BlockAck, and Multi-STA BlockAck frames sent to an HE STA. An HE AP indicates that it supports setting the More Data subfield to 1 in these control response frames by setting the More Data Ack subfield to 1 in the QoS Info field of elements it includes in frames transmitted to the STA.~~

*TGbe editor: Add the following paragraphs as follows: (#5064)*

For an AP MLD, a STA affiliated with a non-AP MLD uses the More Data subfield to indicate to an AP in PS mode affiliated with the AP MLD that more BUs, corresponding to Data frames with TIDs that are mapped to this link by the most recent UL TID-to-link mapping (negotiated TID-to-link mapping or default link mapping, see 35.3.7.1 (TID-to-link mapping)) or Management frames that are not measurement MMPDUs (see 35.3.12.4 (Traffic indication)) are buffered for the AP MLD at the non-AP MLD. The More Data subfield is valid in individually addressed Data or Management frames transmitted by a STA affiliated with a non-AP MLD to an AP affiliated with an AP MLD that is in PS mode and in certain control frames as defined below.

**9.4.1.17 QoS Info field**

*TGbe editor: Change the last paragraph as follows: (#5064)*

AAR