IEEE P802.15

**Wireless Personal Area Networks**

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| Project | IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs) | |
| Title | 802.15.9 Fragmentation Replacement Text | |
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| Re: | [802.15.9 Draft 1.0] | |
| Abstract | [This document describes improvements to 802.15.9 draft 1.0.] | |
| Purpose | [To improve Key Management Protocol 802.15.9] | |
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Replaces Clauses 5 & 7 in Draft-D1.0 802.15.9 (X=5, Y=7)

Note that the following uses the standard MCPS-DATA Service which should not require any modification.

## X.x Data Transfer Control Service

The Data Transfer Control Service provides for:

1. Protocol dispatch using a Protocol Identifier (Protocol ID)
2. Fragmentation/reassembly with Request to Send (RTS)/Clear to Send (CTS) support

One Payload Information Element is defined for the Data Control Service, implementing a Transfer Control Field that allows signaling of the Transfer Type. The Protocol ID associated with the MSDU is in support of the protocol dispatch feature. The RTS/CTS feature can be used to negotiate transfer of a single MSDU or a fragmentation/reassembly sequence. An initial Fragment Transaction Request handshake containing the RTS/CTS is used to ensure the destination device is available to receive a fragmented MSDU.

### X.x.1 MSDU Protocol ID

For any MSDU transfer, a Data Transfer Control IE (DTC IE) is included in the frame to declare a protocol identifier associated with the MSDU. The Protocol ID is the {insert reference to Protocol ID standard database} value for the source and destination protocol handler for the content of the MSDU.

For an MSDU transferred in a single frame the DTC IE will also contain the MSDU payload. An optional RTS/CTS handshake may be requested in a frame preceding the frame carrying the MSDU.

For an MSDU transferred as a fragment sequence, the Protocol ID declared in the DTC IE is associated with the Transaction ID carried in the DTC IEs in the subsequent fragment sequence transfer.

## X.x.2 Fragmentation

The Fragmentation Service is invoked by the MAC to deliver an MSDU exceeding the macFragmentThreshold octet count value. Since this value, by definition, indicates a long frame, the Fragmentation Service applies an RTS/CTS handshake to ensure the destination device is available and able to receive the MSDU transfer.

An initial Request-to-Send (RTS) transmission carries a DTC IE describing the intended MSDU size together with the Protocol ID of the intended recipient protocol entity within the destination device and a Transaction ID.

If the recipient of the frame carrying the RTS is available and able to receive the MSDU a Clear-to-Send (CTS) transmission carrying a DTC IE is transmitted to the RTS source.

Each device shall maintain a monotonically increasing counter which is incremented after each value is assigned to a Transaction ID. All fragments in the same fragment sequence shall carry the same Transaction ID. The combination of {Device Source Address, Transaction ID and Fragment Number} uniquely identifies any fragment in any fragment sequence.

If a device is unable to accept the fragment sequence offered in a received fragment RTS, it may respond with a CTS with:

* a value of zero in the Total MSDU Size to indicate inability to receive the fragment sequence or lack of support for the Protocol ID
* different Total MSDU Size field value indicating total octet count it is able to accept.

If the values of these fields in a received CTS differ from the corresponding RTS field values, the source of the RTS must abandon the fragment transaction and may attempt a new transaction which would satisfy the indicated limits.

The transmission of fragments shall not commence until a CTS has been received with Protocol ID, Transaction ID and Total MSDU Size fields matching a corresponding RTS.

Each fragment in the fragment transaction shall be sent in a Data Transfer Control IE using the Initial Fragment, Additional Fragments or Last Fragment frame control. Frames for which the requested acknowledgement is not received shall be retransmitted using standard frame re-transmission services.

Acknowledgement of the preceding fragment in a fragment sequence shall be received before the next fragment in the fragment sequence is transmitted.

If the requested acknowledgement for the frame carrying a fragment is not received after macFragmentRetryCount attempts the fragment transaction is abandoned and the corresponding MCPS-DATA.confirm shall indicate failure in the same manner as for a failed un-fragmented transfer request.

A fragment sequence may be aborted by transmission of a DTC IE signaling Abort Transaction in the Transfer Control field.

If the next fragment in a fragment sequence is not received macFragmentTimeOut after the last received fragment, the recipient of the fragment sequence may abandon the reassembly operation and discard any received fragment data.

## Y.y Information Elements (IEs)

### Y.y.1. Data Transfer Control IE (DTC IE)

The DTC IE shall be formatted as a Payload IE as defined in { see 802.15.4e-2012 5.2.4.3} with Element ID set to DTC {*request an assigned Payload IE ID from 802.15 ANA*} and Length field set to the appropriate value for the Transfer Type.

The following sections describe the frame exchanges supported using the DTC IE.

Y.y.1.1 DTC IE General Frame Format

The DTC IE consists of a Transfer Control Field followed by a Transfer Frame Field. The Transfer Type field of the Transfer Control Field determines the fields present in the Data Transfer Frame.

Figure 1 provides the General Transfer Control Field for the DTC IE and Figure 2 provides the General Data Transfer Frame.

|  |  |  |  |
| --- | --- | --- | --- |
| Bit:0-2 | 3 | 4 | 5-7 |
| Transfer Type  (0b000 = MSDU  0b001 = Fragment Transaction Request  0b010 = Initial Fragment  0b011=Additional Fragments  0b100=Last Fragment  0b101=Abort Transaction  0b110-0b111=Reserved) | RTS/CTS Control | RTS/CTS  0 = RTS  1 = CTS | Reserved |

Figure 1: General Transfer Control Field

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Octets: 0/2 | 0/2 | 0/2 | 0/1 | 0/n |
| Protocol ID | Transaction ID | Total MSDU Size (Octets) | Fragment  Count | MSDU Payload |

Figure 2: General Data Transfer Frame

Y.y.1.2 Transfer Type processing

Six Transfer Types are defined within the Transfer Control Field of the DTC IE:

1. MSDU – The MSDU Transfer Type supports single MSDU transfer of the size indicated in the Single MSDU Transfer Frame. There are two forms of this transfer:
   1. Using RTS/CTS – If RTS/CTS Control is 1, the MSDU Payload shall be omitted for the RTS and CTS exchanges until agreement is reached on the Total MSDU Size in this Payload or the exchange is abandoned
   2. Without RTS/CTS – When RTS/CTS is 0, the Total MSDU Size is omitted and the MSDU Payload must be included in the Single MSDU Transfer Frame. The recipient must obtain the length of the MSDU payload from the payload IE fields for the DTC-IE.

|  |  |  |  |
| --- | --- | --- | --- |
| Single MSDU Transfer Frame | | | |
| Bit: 0-2 | 3 | 4 | 5-7 |
| Transfer Type (0b000 = MSDU ) | RTS/CTS Control | RTS/CTS  0 = RTS  1 = CTS | Reserved |

Figure 3: Single MSDU– Transfer Control Settings

|  |  |  |  |
| --- | --- | --- | --- |
| Octets: 1 | 2 | 0/2 | 0/n |
| Single MSDU Transfer Control (see Figure 3) | Protocol ID | Total MSDU Size (Octets) | MSDU Payload |

Figure 4: Single MSDU Transfer Frame

1. Fragment Transaction Request – For Fragment Transaction Request Transfer Type, the RTS/CTS mechanism must be used. Only after agreement is reached on the Total MSDU Size will the Initial Fragment, Additional Fragments and Last Fragment Transfer Types effect transfer of the fragmented MSDU. There are two forms of this Fragment Transaction Request:
   1. RTS – This is the request from the transaction originator to the recipient proposing the Total MSDU Size to transfer
   2. CTS – This is the response from the recipient either declining the transfer, agreeing to the Total MSDU Size to transfer or offering a counter-proposal on the size. Note that fragment transfer will not occur until a CTS is received at the transaction originator matching the last RTS sent.

Note that the final agreement on the Total MSDU Size must be noted at the recipient for processing of the Initial Fragment, Additional Fragments and Last Fragment frames. The subsequent Initial Fragment, Additional Fragments and Last Fragment frames will deliver the fragmented MSDU in this payload and the Fragment Number, however, the Total MSDU Size only appears in the Fragment Transaction Request. Additionally, the payload length delivered with each fragment must be obtained by the recipient from the DTC Payload IE since the transaction originator is not required to uniformly size each fragment.

|  |  |  |  |
| --- | --- | --- | --- |
| Fragment Transaction Request (RTS)  Transfer Control | | | |
| Bit: 0-2 | 3 | 4 | 5-7 |
| Transfer Type (0b001 = Fragment Transaction Request) | RTS/CTS Control  (1 = RTS/CTS) | RTS/CTS  (0 = RTS) | Reserved |

Figure 5: Fragment Transaction Request (RTS) – Transfer Control Settings

|  |  |  |  |
| --- | --- | --- | --- |
| Octets: 1 | 2 | 2 | 2 |
| Fragment Transaction Request Transfer Control (see Figure 5) | Protocol ID | Transaction ID | Total MSDU Size (Octets)  (Proposed from originator) |

Figure 6: Fragment Transaction Request (RTS) Transfer Frame

|  |  |  |  |
| --- | --- | --- | --- |
| Fragment Transaction Request (CTS)  Transfer Control | | | |
| Bit: 0-2 | 3 | 4 | 5-7 |
| Transfer Type (0b001 = Fragment Transaction Request ) | RTS/CTS Control  (1 = RTS/CTS) | RTS/CTS  (1 = CTS) | Reserved |

Figure 7: Fragment Transaction Request (CTS) – Transfer Control Settings

|  |  |  |  |
| --- | --- | --- | --- |
| Octets: 1 | 2 | 2 | 2 |
| Fragment Transaction Request Transfer Control (see Figure 7) | Protocol ID | Transaction ID | Total MSDU Size (Octets)  {Confirmed from recipient or Counter Proposal to originator} |

Figure 8: Fragment Transaction Request (CTS) Transfer Frame

1. Initial Fragment - Once the Fragment Transaction Request completes successfully (defined as the sender receiving a CTS matching Total MSDU Size from the last RTS sent), the Initial Fragment is sent with a Fragment Number of 1. The Initial Fragment frame contains:
   1. Protocol ID and Transaction ID – The destination must associate these values in processing the Initial Fragment since the subsequent More Fragments frame(s) will omit the Protocol ID
   2. Fragment Number must be 1 for this frame
2. MSDU payload – The fragment of the MSDU payload delivered with this transmission

The number of octets included in the MSDU payload delivered by this Initial Fragment frame must be computed by the recipient using the Length field of the DTC payload IE.

|  |  |  |  |
| --- | --- | --- | --- |
| Initial Fragment Transfer Control | | | |
| Bit: 0-2 | 3 | 4 | 5-7 |
| 0b010 = Initial Fragment | RTS/CTS Control  (0 = No RTS/CTS) | RTS/CTS  (Ignored) | Reserved |

Figure 9: Initial Fragment– Transfer Control Settings

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Octets: 1 | 2 | 2 | 1 | n |
| Initial Fragment Transfer Control (see Figure 9) | Protocol ID | Transaction ID | Fragment Number | MSDU Payload |

Figure 10: Initial Fragment Frame

1. Additional Fragments – After the Initial Fragment frame, zero, one or more Additional Fragments frames are sent until the total of the payload sizes for all received fragments for this Transaction ID match the Total MSDU Size provided in the original Fragment Transaction Request.

The Additional Fragments frame contains:

1. Transaction ID – as delivered in the Initial Fragment frame
2. Fragment Number – The Fragment Number must increment by 1 for each received Additional Fragments frame for a given Transaction ID else the packets are out of order and the transfer must be abandoned by the recipient
3. MSDU Payload – The fragment of the MSDU payload delivered with this transmission

Note that the recipient must use the Length field from the DTC-IE to determine the length of the MSDU Payload delivered with this fragment.

|  |  |  |  |
| --- | --- | --- | --- |
| Additional Fragments Transfer Control | | | |
| Bit: 0-2 | 3 | 4 | 5-7 |
| 0b011 = Additional Fragments | RTS/CTS Control  (0 = No RTS/CTS) | RTS/CTS  (Ignored) | Reserved |

Figure 11: Additional Fragments– Transfer Control Settings

|  |  |  |  |
| --- | --- | --- | --- |
| Octets: 1 | 2 | 1 | n |
| More Fragments Transfer Control (see Figure 11) | Transaction ID | Fragment Number | MSDU Payload |

Figure 12: Additional Fragments Frame

1. Last Fragment – After the Initial Fragment frame and zero, one or more Additional Fragments frames are sent, the Last Fragment contains the final fragment payload delivery for this Transaction ID.

The Last Fragment frame contains:

1. Transaction ID – as delivered in the Initial Fragment frame and repeated in each subsequent Additional Fragments frame
2. Fragment Number – The Fragment Number must increment by 1 for the last received Additional Fragments frame for the Transaction ID else the packets are out of order and the transfer must be abandoned by the recipient
3. MSDU Payload – The final fragment of the MSDU payload delivered with this transmission

Note that the recipient must use the Length field from the DTC-IE to determine the length of the MSDU Payload delivered with this fragment.

|  |  |  |  |
| --- | --- | --- | --- |
| Last Fragment Transfer Control | | | |
| Bit: 0-2 | 3 | 4 | 5-7 |
| 0b100 = Last Fragment | RTS/CTS Control  (0 = No RTS/CTS) | RTS/CTS  (Ignored) | Reserved |

Figure 13: Last Fragment– Transfer Control Settings

|  |  |  |  |
| --- | --- | --- | --- |
| Octets: 1 | 2 | 1 | n |
| Last Fragment Transfer Control (see Figure 13) | Transaction ID | Fragment Number | MSDU Payload |

Figure 14: Last Fragment Frame

1. Abort Transaction – At any point in the exchange of a fragmented MSDU payload after the completion of the Fragment Transaction Request and prior to the Last Fragment frame for a given Transaction ID, either side of the exchange may send an Abort Transaction to cancel.

The Abort Transaction frame contains:

1. Transaction ID – the Transaction ID for the fragment exchange being cancelled

Note that once an Abort Transaction is received, both the originator and recipient must assume that the Transaction ID has been abandoned. Any subsequent transfer must begin again with a Transaction Request frame with a different Transaction ID.

|  |  |  |  |
| --- | --- | --- | --- |
| Abort Transaction Transfer Control | | | |
| Bit: 0-2 | 3 | 4 | 5-7 |
| 0b101 = Abort Transaction | RTS/CTS Control  (0 = No RTS/CTS) | RTS/CTS  (Ignored) | Reserved |

Figure 15: Abort Transaction– Transfer Control Settings

|  |  |
| --- | --- |
| Octets: 1 | 2 |
| Abort Transaction Transfer Control (see Figure 15) | Transaction ID |

Figure 16: Abort Transaction Frame

Y.y.1.3 – RTS/CTS Processing using DTC IE frames

If the Transfer Type field value indicates an MSDU in a single frame:

* The RTS/CTS Control field set to 0 indicates that no RTS/CTS handshake is required and the MSDU is carried in the current DTC IE frame. The RTS/CTS field is not used and should be set to 0.
* The RTS/CTS Control field set to 1 indicates that an RTS/CTS handshake is required before the MSDU can be sent:
  + The RTS/CTS field set to 0 indicates the current frame is an RTS handshake. The Total MSDU Size field must be set to the size of the entire proposed MSDU transmission. The MSDU payload field is omitted.
  + The RTS/CTS field shall be set to 1 to indicate the current frame is a CTS handshake. If the Total MSDU Size matches the field received in the RTS, the transfer is agreed. Otherwise, the CTS Total MSDU Size contains a counter proposal on transfer size from the destination. Transmission of the actual MSDU Payload must not occur until a CTS is received matching the RTS.
  + Once the RTS/CTS Total MSDU Size are in agreement, the sender shall use the Single MSDU frame with RTS/CTS Control set to 0 and the agreed Total MSDU Size to transfer the MSDU Payload to the destination.
* The Protocol ID field shall be set to the value of the {insert reference to Protocol ID Authority} identifier for the source/destination MAC Client protocol handler for the MSDU.

If the Transfer Type field value indicates an MSDU transaction in a sequence of fragments (Fragment Transaction Request):

* The RTS/CTS Control field shall be set to 1.
* The RTS/CTS field shall be set to 0 to indicate the current frame is an RTS handshake or shall be set to 1 to indicate the current frame is a CTS handshake.
* The Protocol ID field shall be set to the value of the {insert reference to Protocol ID Authority} identifier for the source/destination MAC Client protocol handler for the MSDU.
* If the RTS/CTS field value indicates an RTS:
  + The Transaction ID field shall be set to the next value of a monotonically increasing counter maintained by the device
  + The Total MSDU Size field shall be set to the number of octets in the un-fragmented MSDU.
* If the RTS/CTS field value indicates a CTS:
  + The Transaction ID field shall be set to the value of the corresponding RTS Transaction ID field
  + The Total MSDU Size field shall be set to:
    - 0 to indicate the device is not available to receive data or the Protocol ID is unknown. If received, the originator should abandon the fragmented transfer attempt.
    - the corresponding RTS Total MSDU Size field value to indicate the device is available to receive the fragment sequence
    - a value less than the corresponding RTS Total MSDU Size field value to indicate the device is available to receive a data transfer but has insufficient resources for the MSDU offered and the source device should attempt a new data transfer within the field value.

Y.y.1.4 – Fragmentation Operations using DTC IE frames

A fragmentation operation using DTC IE frames begins with the originator sending a Fragment Transaction Request frame with the following contents:

1. Protocol ID – A registered protocol dispatch value known to both the originator and recipient
2. Transaction ID – A unique value created by the originator covering the set of fragments that comprise a single MSDU to be transferred. The originator should not re-use Transaction IDs until roll-over requires re-use.
3. Total MSDU Size – The size of the un-fragmented MSDU to be transferred using this Transaction ID

The originator and recipient exchange Fragment Transaction Request frames until both originator and recipient agree on the Protocol ID and size of the un-fragmented MSDU to be transferred.

Once agreement is made between the originator and recipient on the Protocol ID and MSDU size, the originator will:

1. Send the Initial Fragment frame with the Protocol ID, Transaction ID, the Fragment Number set to 1 and the partial MSDU payload. Note it is entirely up to the originator as to the size of each partial MSDU fragment to send. The recipient must obtain the length from the DTC IE to determine the number of octets in the MSDU payload
2. Send zero, one or more Additional Fragments frames with the Transaction ID agreed to in the Fragment Transaction Request, a monotonically increasing Fragment Number (for each Additional Fragment frame) and the fragmented MSDU payload. Note that the originator may vary the size of each fragment transmitted according to its internal processing requirements.
3. Send the Last Fragment frame with the Transaction ID agreed to in the Fragment Transaction Request that signifies the final delivery of the entire MSDU agreed to between originator and recipient using Transaction ID.

At any time in the process after the Fragment Transaction Request is agreed to up to the Last Fragment, either the originator or recipient can send an Abort Transaction frame to terminate the MSDU transfer. Upon receipt of an Abort Transaction, the originator must stop sending MSDU fragments and the recipient may discard any fragments received using the affected Transaction ID.

## Z.z MAC PIB Attributes

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Attribute | Type | Range | Default Value | Description |
| macFragmentThreshold | Integer | - | 1023 | Largest un-fragmented MSDU size |
| macFragmentReTryCount | Integer | - | 2 | Maximum number of re-transmission attempts for a fragment |
| macFragmentTimeOut | Integer | - | 10 seconds | Maximum time between received fragments in a fragment sequence, as referenced to the end of the frame carrying the last received fragment |

Figure 17: MAC IB Attributes