Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: Comment Resolution LB-100

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Abstract: Comment Resolution

Purpose: Comment Resolution for comments collected from LB-100

Introduction:

The comment resolutions in this revision provide resolutions for the following CIDs:

2002, 2006, 2051, 2053, 2058, 2060, 2067, 2070, 2072, 2075, 2076, 2080, 2081, 2082, 2085, 2098, 2109, 2110, 2111 and 2119.

Comment ID: 2060, 2072, 2119

Comment: The draft does not meet the 5C requirement of uniqueness. There are already 6 FSK PHYs defined in 802.15.4, with data rates ranging from 2.4 kb/s to 400 kb/s operating in all of the bands already identified for the proposed ULP PHY. There is nothing in the current definition of the ULP FSK PHY that enables it to be lower power than the existing FSK PHYs.

Proposed change: Delete Clause 31 and references to the ULP FSK PHY.

Resolution: Rejected. The PAR states: "This amendment defines an ultra low power (ULP) physical layer .... supporting typical data rates up to 1 Mbps." The ULP-GFSK PHY is supporting rates up to 1Mbps, no other FSK PHY in 15.4 supports this. The highest FSK data rate currently defined in 802.15.4 is 400kb/s which is only specified for Japan. The highest rate in other bands is only 200kb/s. Using the higher data rates as specified in the ULP-GFSK PHY drastically reduces the on-time which conserves energy.

In addition the ULP-GFSK PHY introduces unique features that have the potential to prolong battery life such as Asymmetric Link Network (ALN), Rate Switch and overhead reduction in SHR and PHR. See the annex on page 24 to 26 at the end of this document.

Comment ID: 2070 – slide 1 of 2

Comment: There's a long list at and below this line of things that happen if other things are "supported." This is bad form, since there's often debate about the meaning of the term "supported." I think they should all be of the form, "shall be set to one if the value of macTimeWasted PIB parameter is TRUE, otherwise it shall be set to zero." That makes things clear. This comment on D1.0 was rejected, with the explanation that, "While I see the point in the comment, not all features have an according PIB attribute. The term "supported" is widely used in the capabilities IEs of other amendments as well." This means that, since others have done a poor job, I can, too, and isn't a philosophy likely to improve the standard.

Proposed change: Avoid use of the word "supported." Explicitly define when things occur, and when they do not. (Use of PIB parameters is optional, and was only used as an example.) Something, somewhere, must indicate whether something is "supported." Otherwise, how is the device itself to know?

Comment ID: 2070 – slide 2 of 2

Resolution: Revised: Change text in 5.2.4.39 (changes in green):

The Rate Switch field shall be set to one if rate switch mode, as described in 31.3, is supported and shall be set to zero otherwise. If the Rate Switch field is set to one a 4-GFSK MCS from Table 22 with double data rate is supported for each of the supported MCS with modulation index one. This means that the device shall be responsive to both states of the received Rate Switch bit in the PHY header as described in 31.3. It also means that the device shall be capable of transmitting a Rate Switch as described in 31.3, however, it may omit the Rate Switch.

The Short PHR field shall be set to one if the short PHR, as defined in 31.1.4, is supported and shall be set to zero otherwise. This means that the device shall be responsive to both states of the received Short PHR bit in the PHY header as described in 31.1.3 and 31.1.4. It also means that the device shall be capable of transmitting a Short PHR field as described in 31.1.4 and a Long PHR as described in 31.1.3.

The FEC field shall be set to one if FEC, as described in 31.2.7, is supported, and shall be set to zero otherwise. This means that the device shall be responsive to the received SFD as described in 31.1.2 and 31.2.7 in both FEC enabled and FEC disabled cases. It also means that the device is capable of transmitting with FEC enabled as described in 31.1.2 and 31.2.7, however, it may transmit without FEC enabled.

The TPC field shall be set to one if TPC, as described in 5.1.9, is supported and shall be set to zero otherwise. This means that the device shall be responsive to the received ULP-GFSK TPC IE as described in 5.1.9 when its power control range allows this.

The Frequency Band Supported field is a bitmap in which a bit, bn, is set to one if the frequency band corresponding to the frequency band identifier in Table 2 is supported and shall be set to zero otherwise. The supported frequency bands shall be supported in both transmit and receive.

The PHY MCSLevels Supported field is a bitmap in which a bit, bn, is set to one if the MCS corresponding to the MCS Identifier in Table 21 is supported and shall be set to zero otherwise.
A device shall be capable to receive the MCS as indicated in its transmitted ULP-GFSK Device capabilities field. The device is permitted to transmit in any another MCS.

ALN comment resolution – slide 1 out of 8

Comment ID: 2002

Comment: The ALN mode seems nothing more than sending Enhanced Beacons containing the ULP-GFSK Link Specification IE. There is no need to introduce an "ALN mode“.

Proposed change: Change sentence to: "An ALN is formed when a device, usually the PAN coordinator advertises the presence of the network by sending Enhanced Beacons containing the ULP-GFSK Link Specification IE, as described in 5.2.4.40, upon receipt of a MLME-START.request from a higher layer."

Resolution: AiP

Comment ID: 2006

Comment: ALN capability is missing in the feature field.

Proposed change: Add ALN to bit 4 in the feature field. Add text below line 18: "The ALN field shall be set to one if ALN as described in 5.1.2.6, is supported and shall be set to zero otherwise.

Resolution: AiP

ALN comment resolution – slide 2 out of 8

Comment ID: 2075

Comment: ALN can't work as described as there is no way in 802.15.4 to prevent peer-to-peer communications. The formation of a star PAN is out of scope of the standard. Devices have no way of knowing is a particular PAN is a star, mesh or peer-to-peer. Hence, it is not possible to mandate the behavior described in this subclause. Furthermore, the PAN coordinator has no way of knowing what the specific data rate configuration should be for a device in a PAN and, in any event, the optimal MCS changes with time, but the proposed system has no way of resolving this. It is broken in theory, in practice and in all details.

Proposed change: Delete ALN, all descriptions and frame formats.

Resolution: Rejected

ALN comment resolution – slide 3 out of 8

Comment ID: 2076

Comment: This subclause doesn't deal with the case were a device hears multiple beacons, each of which has different settings for the link. What does a device do in this case?

Proposed change: Delete ALN, all descriptions and frame formats.

Resolution: Rejected. ALN is only permitted in a star topology. Beacons not belonging to the PAN of the ALN are ignored. In addition the “ULP GFSK Link Specification IE” is deleted as part of the ALN comment resolution.

Comment ID: 2077

Comment: The statement “The ULP GFSK Link Specification may be used in Enhanced Beacon frames” is meaningless because it doesn't constrain the use of the IE. It may be used in the Enhance Beacon frame, but it may also be used in any other frame as there is no restriction on this anywhere in the draft.

Proposed change: Change “may be used” to be “shall only be used”

Resolution: AiP. The “ULP GFSK Link Specification IE” is deleted as part of the ALN comment resolution.

ALN comment resolution – slide 4 out of 8

Comment ID: 2082

Comment: "The set of PHY parameters at which the device successfully heard a valid Enhanced Beacon are used for further downlink transmissions, i.e. transmissions from the PAN coordinator to the ULP device" is not a valid condition. The PAN coordinator does not know which Enhanced Beacon was "successfully hear" by the ULP device, hence it cannot be required to maintain this set of PHY parameters. Furhtermore, it may want to change them based on the dynamic nature of a wireless system.

Proposed change: Delete the sentence.

Resolution: Accepted

Comment ID: 2084

Comment: The description of macAlnEnabled is not correct. Nowhere does it say if this is set by the next higher layer to put a PAN coordinator into ALN mode or if it is a notification by the MAC that it is in ALN mode. There are not shalls associated with the PIB attribute, hence it has no effect on the device. This makes it useless and so it needs to be deleted.

Proposed change: Delete the PIB entry macAlnEnabled.

Resolution: Accepted

ALN comment resolution – slide 5 out of 8

Comment ID: 2098

Comment: "It is a reasonable assumption that in a star network the central concentrator device can be equipped with more potent hardware, more sophisticated algorithms and be free from any power consumption constraints (i.e. it is mains powered)." is not a reasonable assumption. Bluetooth, for example, is a star network in which this assumption is generally false.

Proposed change: Delete the sentence.

Resolution: Accepted

Comment ID: 2100

Comment: This exhibits one of the mistakes of ALN, that the same parameters are used for all uplinks and (possibly different ones) for downlinks. In the network, the links are dynamic and dissimilar. Hence one set of fixed parameters is the worst way to configure a network in which the devices have multiple options. A much better method is to allow the devices to individually select the parameters based on the link conditions at that time.

Proposed change: Delete ALN as it is broken and not useful.

Resolution: Rejected. There are several examples of successful standards that use one set of modulation parameters including Bluetooth, ZigBee and Mbus. Also the Rate Switch feature is not excluded from ALN which provides a second modulation type.

ALN comment resolution – slide 6 out of 8

Comment ID: 2111

Comment: I assume this IE is processed by the upper layer after the active or passive scan. This should be explictly mentioned.

Proposed change: Add text saying where this IE is processed. Also might add note that upper layer can do security policy decisions after receiving this thus this do not have MAC security issues.

Resolution: Rejected. As part of the resolution for ALN issues the “ULP GFSK Link Specification” IE is deleted.

ALN comment resolution – slide 7 out of 8

Resulution Part-1:

Change text and title of 5.1.2.6:

5.1.2.6 Formation of an Asymmetric Link Network (ALN)

An Asymmetric Link Network (ALN) can only be formed in a star network. The formation of a star network is described in 4.3.1. A device being part of an ALN shall employ any of the ULP-GFSK MCSs and shall have a different MCS for transmit compared to its receive MCS. The formation of an ALN may be useful when the central coordinator device employs a higher receive sensitive and transmit power compared to the other devices in the network. In an ALN the coordinator is preferably a mains powered device which may leverage it's excess in sensitivity and transmit power to alleviate these requirements in the other devices of the network. Lowering the requirements for transmit power and receive sensitivity may help to prolong battery life. The MCSs used by the ULP-GFSK PHY are designed to leverage the concept op ALN. The GMSK modulation in combination with FEC allows for high receive sensitivity where as the GFSK modulation allows for low power and low cost implementations with moderate receive sensitivity. As an example the coordinator device may use a coherent receiver optimized for MCS-6 (500 kbps at modulation index 0.5) with FEC capability to boost its receive sensitivity. To reduce energy consumption, the other devices may be equipped with a non-coherent FSK receiver optimized for MCS-4 (500 kbps at modulation index 0.72) without FEC decoding capability but with FEC encoding capability. In an ALN the link budget in the uplink direction is characterized by a relatively low transmit power and high receive sensitivity while in downlink direction that is reversed. This helps to balance the link budget between uplink and downlink. The MCS per device shall be configured as part the ALN deployment. If MCS levels with different symbol durations are employed for uplink and downlink, all calculations depending on symbol durations shall use the longer symbol duration.

ALN comment resolution – slide 8 out of 8

Part-2:

Remove all occurrences of "ULP-GFSK Link Specification" including related text:

- Table 4d, delete **ULP-GFSK Link Specification** row of table.
- Delete sub clause: 5.2.4.40

Part-3:

Remove all occurrences of "macAlnEnabled" including related text:

- Table 52a, delete **macAlnEnabled** row from table

Comment ID: 2051 and 2053 (this comments are identical)

Comment: Many of the PHYs within the IEEE 802.15.4 Standard may be implemented in a Ultra Low Power applications not just the ULP Draft standard PHYs ULP-TASK and ULP-GFSK

Proposed change: Eliminate the ULP prefix to the PHY names ULP-GFSK and ULP-TASK

Resolution: Rejected. The commenter was approached. It was explained that the ULP (Ultra Low Power) prefix was chosen because of the focus on reducing power/energy consumption as is outlined in in PAR. As a result two PHY modes are introduced with potential to prolong battery life time. The techniques applied including their benefits are included in the annex on page 24 to 26 at the end of this document. The commenter was also invited to provide suggestions for a more appropriate name but so far the BRC didn't receive any suggestions.

Comment ID: 2058

Comment: Resolution to CID # 1154 is not satisifactory, nor was the commenter approached about the resolution to it.

Proposed change: The resolution does not provide a sound enough reason/justification. A more thorough explanation, citing some actual reference #'s is needed, perhaps in an informative annex, and should be highly considered.

Resolution: Revised. The commenter was approached. It was agreed that the BRC would provide a more thorough explanation plus references. This explanation is now included, see the annex on page 24 to 26 at the end of this document.

Comment ID: 2067

Comment: Sending a request to increase signal strength by 30 dB in an ack doesn't make a lot of sense to me, since the original power level was high enough to receive the packet one is acking, but I don't suppose it hurts anything.

Proposed change: I would have had things asymmetrical, so that there was more decrease and less increase range, but …

Resolution: Rejected. Like the commenter mentioned the increase of 30dB doesn’t hurt anything. Also, it will complicate the 6 bits representation when it is asymmetric.

Comment ID: 2080

Comment: There is no reason to restrict the use of power control the the ULP GFSK PHY. If it is really useful then it should be allowed for all PHYs. Devices that don't implement the IE or implement power control can simply ignore it. The response was “TASK targets at a different set of applications that operate in shorter ranges. Therefore power control is not necessary. Implementors can do power control from the higher layers.”, my comment was not restricted to TASK, but all of the other 20+ PHYs in 802.15.4. Furthermore, the higher layers cannot and should not do power control as there are a) no mechanisms in the MLME to support this and b) no timely feedback to the next higher layer to enable it to make this decision. The only reason to limit it to ULP GFSK is because it is not useful at all, which is true.

Proposed change: Since the group does not find it useful outside of ULP GFSK, then it must be useless, so delete the power control IE and all associated descriptions.

Resolution: Rejected. TPC has real potential to save energy and as such it is useful. To claim TPC as a generic feature is out of scope of TG-4q.

Comment ID: 2081

Comment: In a CSMA/CA system, such as 802.15.4, having devices reduce power because they are close will lead to a higher number of collisions and, hence, retransmissions. The reason for rejection was “This would mean the best strategy in a CSMA/CA network would be to always use the highest possible transmission power. This can hardly be regarded as an ultra low power approach.” is correct in that it the way the access method works and it also results in lower power use overall by reducing the number of retransmissions. The PA only contributes a small amount to the devices power usage, hence transmitting at full power is the best way to save power. “The network operator should be given the possibility to use a standardized TPC mechanism if he thinks this suits his needs.” There is not necessarily a network operator in 802.15.4, TPC doesn't work and breaks CSMA/CA, which is why it should not be done as described in this method.

Proposed change: Delete the transmission power control function and associated frame formats. It doesn't work, it breaks CSMA/CA and it doesn't save power.

Resolution: Rejected. TPC will not break CSMA/CA as long as the power control is reduced as appropriate. E.g. a close-by device may blast the receiver with -40dBm. With TPC that may be reduced to -43dBm which will not break CSMA/CA but it may save energy. As an example: ~4mW power reduction would be obtained when the RF power is reduced from +5dBm to +2dBm assuming a PA efficiency of 40%. On the 15mW budget as mentioned in the PAR this is a significant saving.

Comment ID: 2083 slide 1 of 2

Comment: The introduction is not supposed to be a re-statement of the scope. Instead it is supposed to give context to the standard. You should provide some history and justification for the standard.

Proposed change: Read the most IEEE Style Manual regarding what should be put in the Introduction and replace with appropriate text.

Comment ID: 2083 slide 2 of 2

Resolution: Revised. Replace text in Introduction on page vi with:

This amendment specifies two alternate PHYs, ULP-TASK and ULP-GFSK, in addition to those of IEEE Std 802.15.4-2011. The amendment also defines those MAC modifications needed to support their implementation. Both PHYs are specified for 2.4GHz and several sub-GHz bands using multiple data rates up to 1 Mbps.

The ULP-TASK PHY specifies a physical layer based on amplitude shift keying with ternary sequence spreading. This PHY allows implementation of transceivers with low complexity, and enables ultra-low power consumption. As an important feature, this PHY also supports communications in both coherent and non-coherent modes of reception, thereby allowing tradeoff between the receiver complexity and performance.

The ULP-GFSK PHY specifies a physical layer based on Gaussian frequency shift keying. This PHY provides the ultra-low power benefits by the availability of higher data rates, reduced overhead in the PPDU, TX power control and an option to create asymmetric link~~s~~ networks. The asymmetric link networks allow reduction of the transmission power and receiver sensitivity requirements in the end devices which further prolong battery life. In addition, the ULP-GFSK PHY provides options to interoperate with the existing SUN-FSK PHY. A wide range of applications will benefit from the energy savings enabled by the ULP-GFSK PHY including electronic shelf labels, home area networks, smart irrigation systems and smart metering.

Comment ID: 2085

Comment: The use of macTPCEnabled is not needed (and its description in Clause 6 and Clause 5 is incorrect). The MAC would decide if it needs to do TPC.

Proposed change: Delete macTPCEnabled, it is not needed. The MAC will decide if it is going to send the IE and if it will change its power in response to the IE.

Resolution: Accepted.

Comment ID: 2086

Comment: Allowing a variable preamble length in 15.4g was a bad compromise that should not be repeated. The response "Variable preamble length is not a single mistake by 4g. It can also be found in 4k and 4m (if it is still a mistake, that's quite a few mistakes already…)", yes that is quite a few mistakes, stop making them. 4k and 4m were not made aware of the MAC issues and repeated the mistake. "Also variable length might be reasonable to support networks for different scenarios.", and yet no scenarios are given, hence there is no reason to repeat the mistake.

Proposed change: Set the preamble length to be 4 octets, fixed. 2 is too short and 4 is sufficient.

Resolution: Rejected. The optimal preamble length depends the use case. E.g. when battery life is limited by TX power consumption a short preamble is preferred. When antenna diversity is anticipated a longer preamble may be more appropriate. The optimal preamble length can be selected upon deployment of a PAN.

Comment ID: 2109

Comment: The appendix B.3 says this IE is used association request command frame, should it be mentioned also here?

Proposed change: Add text saying this used for association request command frames.

Resolution: Revised. The Annex will be removed. Instead the amendment will refer to document 15-15-0118-00-004q where the association is not discussed since the ALN has been simplified. See resolution on CID-2075.

Comment ID: 2110 slide 1 of 2

Comment: As this PHY MCS Levels only indicate the 2-GFSK MCS numbers, how does one know whether the other end supports 4-GFSK MCS modes, so it can use them. This is same as my CID 1007 which was rejected by saying that 4-GFSK modes are controlled by Rate Switch bit. This does not change the fact that when the device tries to tell the other end which modes it support it might want to tell that it support both 4-GFSK and 2-GFSK modes, or is this only telling the supported modulation formats for the PHR not for the PDSU?

Proposed change: If the PHY MCS Levels Supported field will only specify the format of the PHR (which is always using 2-GFSK) then that should explictly mentioned here, and also add not that there is no way to know what 4-GFSK formats the other end supports. Or if the RateSwitch is something that must be same for the whole network and if someone is using RateSwitch of 1 then everybody uses that and then the PHY MCS Levels can also indicate stuff rrom table 22 then there needs to be text explaning how 0a is mapped to certain bit.

Comment ID: 2110 slide 1 of 2

Resolution:

Revised: Change line 21 and 22 in to:

The PHY MCS Levels Supported field is a bitmap in which a bit, b_{mcsi}, is set to one if the MCS corresponding to the MCS Identifier mcsi in Table 21 is supported and shall be set to zero otherwise. When Rate Switch is supported then for each MCS that is supported there shall be support for a operating mode, selected from Table 22, that is using the same symbol rate as the supported MCS.

Annex

Merits of the ULP-GFSK PHY – slide 1 of 2

Asymmetric Link Networks

IEEE 802.15.4q introduces the Asymmetric Link Networks (ALN) which may lead to energy savings in a star network by alleviating requirements such as transmitter output power and receive sensitivity.

An Asymmetric Link Network (ALN) may be formed in a star network. A device being part of an ALN will have a different MCS for transmit compared to its receive MCS. The formation of an ALN may be particularly useful when the central coordinator device employs a higher receive sensitive and transmit power compared to the other devices in the network. In an ALN the coordinator is preferably a mains powered device which may leverage its excess in sensitivity and transmit power to alleviate these requirements in the other devices of the network. Lowering the requirements for transmit power and receive sensitivity helps to prolong battery life.

As an example the coordinator device may use a coherent receiver optimized for MCS-6 (500 kbps at modulation index 0.5) with FEC capability. Given a proper receiver design and using FEC combined with the differential pre-coding and GMSK may improve the receive sensitivity by up to 8 dB (see document 15-14-0072-00-004q-Joint ULP-GFSK PHY layer proposal). The improved sensitivity in the coordinator allows the end nodes to operate with a lower transmit power.

To reduce energy consumption, the other devices may be equipped with a non-coherent FSK receiver optimized for MCS-4 (500 kbps at modulation index 0.72) without FEC decoding capability but with FEC encoding capability. The higher transmit power of the coordinator permits the end devices to operate with less sensitivity which allows for a current reduction in their receiver components such as LNA and demodulator and absence of FEC decoding.

In an ALN the link budget in the uplink direction is characterized by a relatively low transmit power and high receive sensitivity while in downlink direction that is reversed so that the link budget in both directions is balanced.

Merits of the ULP-GFSK PHY – slide 2 of 2

Options for higher data rate

Higher data rate capabilities in IEEE 802.15.4q improve the energy efficiency further, since on the air time is reduced. The highest rate specified in the 4q draft 1 Mbps which is 2.5 times higher than available in the MR-FSK PHY. The added advantage is a lower interference footprint resulting in fewer collisions and retransmissions.

Rate Switch

The Rate Switch is signaled in the PHR by the Rate Switch bit. When enabled the Rate Switch is seamless between PHR in 2GFSK and PSDU in 4GFSK. The modulation indices of the 2GFSK and 4GFSK modulation types are specified such that the outer deviation is identical and hence the modulation bandwidth is close to identical. The seamlessness, simplicity and ease of implementation makes the Rate Switch feature unique. Nodes communicating with sufficient link budget can use the Rate Switch to reduce the on time in both transmitting node as well as the receive node and save energy on both sides of the link.

Overhead Reduction

IEEE 802.15.4q is energy efficient as it utilizes shorter preambles and PHY header. Consequently, 15.4q is is more energy efficient than PHY 802.15.4f, 802.15.4g and 802.15.4k. As an example: transmission of 4 data Bytes, followed by a short ack. In MR-FSK this will take 23 Bytes (PANID and short addresses) for the data transfer and 13 Bytes for the short ack. Using the ULP-GFSK PHY both data transfer and short ack are reduced by 3 Bytes = 20% saving. These savings are in addition to afore mentioned savings.

As far as coexistence, there is a coexistence assurance document available. The ULP-GFSK PHY can coexist with the MR-FSK PHY, in fact it could interoperate if the long PHR is being used by the ULP nodes. If interoperation is not desired the ULP devices could be restricted to use only the short PHR.

For more detail see document # 15-15-0118-01-004q