**IEEE P802.15**

**Wireless Personal Area Networks**

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# Acronyms and Abbreviations

|  |  |
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| **MAC** | Media Access Control |
| **PHY** | Physical layer |
| **DSME** | Deterministic and Synchronous Multichannel Extension |
| **TSCH** | Time Slotted Channel Hopping |
| **LE** | Low Energy |
| **LL** | Low Latency |
| **ESOR** | Enhanced Security and Overhead Reduction |
| **CCA** | Clear Channel Access |
| **LQI** | Link Quality Indication |
| **ED** | Energy Detect |
| **CSMA** | Carrier Sense, Multiple Access |
| **CSL** | Coordinated Sampled Listening |
| **RIT** | Receiver Initiated Transmission |
| **EBR** | Enhanced Beacon Request |

# Introduction

This document is supplemental to Annex E of IEEE Std 802.15.4-2006 that describes the coexistence properties of IEEE Std 802.15.4. Annex E provides an overview of the mechanisms that are defined in the standard which include:

* CCA (clear channel assessment)
* Dynamic channel selection
* Modulation
* ED and LQI (energy detect and link quality indication)
* Low duty cycle
* Low transmit power
* Channel alignment
* Neighbor piconet capability

This document will describe the enhancements to the 802.15.4 Media Access Control (MAC) sublayer (there are no PHY changes within this amendment) and discuss their impact on coexistence.

# Background

**Excerpts from 802.15.4e PAR**

**Title:** IEEE Standard for Information Technology - Telecommunications and Information Exchange Between Systems – Local and Metropolitan Area Networks - Specific Requirements - Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low Rate Wireless Personal Area Networks (WPANs) - Amendment: Amendment to the MAC sub-layer

**5.2 Scope:** The intention of this amendment is to enhance and add functionality to the 802.15.4-2006 MAC to a) better support the industrial markets and b) permit compatibility with modifications being proposed within the Chinese WPAN. Specifically, the MAC enhancements are limited to:

1. TDMA: to provide a)determinism, b)enhanced utilization of bandwidth
2. Channel Hopping: to provide additional robustness in high interfering environments and enhance coexistence with other wireless networks
3. GTS: to increase its flexibility such as a) supporting peer to peer, b)the length of the slot, and c) number of slots
4. CSMA: to improve throughput and reduce energy consumption
5. Security: to add support for additional options such as asymmetrical keys
6. Low latency: to reduce end to end delivery time such as needed for control applications

**5.4 Purpose:** This functionality facilitates Industrial applications (such as addressed by HART 7 and the ISA100 proposed standards), and those enhancements defined by the proposed Chinese WPAN standard that aren't included in TG4c. This amendment addresses coexistence with wireless protocols such as 802.11, 802.15.1, 802.15.3, and 802.15.4.

**5.5 Need for the Project:** Industrial applications have requirements that are not addressed by the existing standard such as low latency, robustness in the harsh industrial RF environment, and determinism. The Chinese Wireless Personal Area Network standard has identified enhancements to improve network reliability and increase network throughput to support higher duty-cycle data communication applications.

**Excerpt from 802.15.4e “5 Criteria” document (15-07-861-00)**

*“A coexistence assurance document will be submitted to the 802.19 TAG.”*

# TG4e Overview

Task Group 4e is drafting a proposed amendment to the 802.15.4-2006 standard to enhance MAC behavior to benefit Industrial wireless applications, Chinese WPAN applications, and also to assist the PHY amendment efforts of TG4f (RFID) and TG4g (SUN).

The TG4e efforts have been categorized into the following groups: Deterministic and Synchronous Multichannel Extension (DSME), Time Slotted Channel Hopping (TSCH), Low Latency (LL), Enhanced Security/Overhead Reduction (ESOR), Low Energy (LE), TG4f (4f), TG4g (4g), Enhanced Beacon Request (EBR), Fast Association (FastA), and additional device metrics (Metrics).

It is important to note that many of these changes are intended to facilitate and standardize current implementations of the 802.15.4 standard, hence these changes aren’t envisioned to cause any degradations to communications, rather they should enhance device coexistence.

## DSME

This effort enhances the MAC’s beacon mode to better serve applications such as the Chinese WPAN and other networks needing a periodic network beacon with many device slots and multiple coordinators. These enhancements include:

* + Providing scalability mechanisms to allow the network size and number of nodes to be increased
  + Adding adaptive channel agility and channel hopping to enhance reliability in interference limited environments
  + Adding coordination between devices to increase determinism and reduce self interference within the network

## TSCH

This effort enhances the MAC’s non-beacon mode to better serve Industrial wireless process-control applications such as Wireless HART and ISA100.11a networks. Such industrial applications have needs for robust, deterministic, secure, and highly available communications to control the manufacturing process in, for example, Process automation, Factory automation, etc.

To have less interference with different radio equipment, in industrial area it is recommended to follow the coexistence management process specified in IEC/TS 62657. This coexistence management approach is much more efficient to increase coexistence in an industrial environment as opposed to the victim approach that is in use in public areas.

These networks feature time scheduled slots for each device along with frequency hopping and channel management. It should be noted that the cited standards already exist and while the proposed changes to the MAC facilitate the noted standards and applications, even without the MAC changes the use in Industrial environments will continue.

The MAC enhancements include:

* + Change of CSMA back-off to a slotted mechanism resulting in longer back-offs
  + Adds adaptive channel hopping to enhance reliability in interference limited environments
  + Enables device coordination to reduce self interference
  + Advertisements to inform new devices of the presence of the network and its characteristics

## Low Latency

This effort enhances the MAC’s beacon mode to better serve wireless factory automation applications requiring high determinism and low latency for transmission e.g. sensor data in ≤ 10 ms for 15 devices. These enhancements include:

* + New frame format with reduced overhead to reduce frame durations

## Low Energy

This effort enhances the MAC by adding a Coordinated Sampled Listening (CSL) and Receiver Initiated Transmission (RIT) to MAC with the following advantages:

* + CSL and RIT allow low duty cycle devices to access the network with reduced energy usage
  + RIT uses std 802.15.4 CSMA for low duty cycle transmissions
  + CSL provides a quick succession of transmit frames

## Overhead Reduction

Although 802.15.4 has always intended to provide a low overhead MAC, the effort in this group is to allow the higher layers to eliminate many MAC fields previously required, in an effort to provide the minimum frame overhead to allow applications to use this standard that are dependent upon very low overhead.

## Enhanced Security

New, optional secured acknowledgement is longer than non-secured acknowledgement but allows networks to reduce false acknowledgements

## Fast Association

The original 802.15.4 association operation included a minimal fixed time for association; this effort removes that fixed time along with the energy expended during that fixed time.

## Added Metrics

The original 802.15.4 standard included very minimal metrics for reporting channel access performance, this effort adds additional metrics to allow a network management function to better facilitate network performance

# Impact

## DSME

It is anticipated that this effort will enhance coexistence by:

* + Adaptive channel agility and channel hopping will enhance reliable links (hence fewer retransmissions) in interference limited environments
  + Adding coordination between devices to reduce self interference within the network
  + Providing scalability mechanisms to allow the network size and number of nodes to be increased without a subsequent increase in collisions

## TSCH

The changes for this mode have been shown via existing standards, such as ISA100.11a and IEC62591, to:

* + enhance reliability in interference limited environments
  + reduce traffic per channel
  + allow for channels occupied by other networks to be “black-listed” and therefore not used via adaptive channel agility
  + coordinate all device communications to minimize self interference and therefore significantly reduce retransmissions due to collisions
  + achieve higher traffic without performance degradation of non-802.15.4 services

## Low Latency

Attributes for this mode, reduced MAC overhead and coordinated time slots for each device enhance coexistence by reduced transmit durations and minimal collisions (hence retransmissions).

## Low Energy

The mechanism used to reduce energy also enhances coexistence by reducing transmission durations and by coordinating devices.

## Overhead Reduction

By allowing the higher layers to delete unnecessary fields from the MAC header, the net effect of this effort is reduced transmit durations which enhances coexistence with other devices.

## Enhanced Security

Although the secured acknowledgement is longer than the current non-secured acknowledgement, it allows the higher layers to use the enhanced ACK rather than sending a longer data frame acting as a secured acknowledgement (such as in ISA100.11a and IEC62591). This effectively assists coexistence due to the reduced transmissions.

## Fast Association

The reduced time during an association is a benefit to a device that desires a quick association without affecting coexistence behavior.

## Added Metrics

The additional metrics allow networks to chose the best routing paths which results in fewer transmissions (enhancing coexistence) and provides additional information on issues caused by interference allowing the network to avoid bad channels and hence reduce retries.

# Conclusion

As stated at the beginning of this document, the 802.15.4e amendment standardizes upper layer behaviors already used by standards using 802.15.4 as their MAC/PHY. The rationale for moving these behaviors down to the MAC is to standardize their implementations across different applications. Accordingly, these changes are “coexistence neutral” since the behaviors are not new.

Furthermore, the 802.15.4e task group believes that the proposed MAC changes could be used by higher layers to enhance network performance by providing tools for device coordination and optimize the use of the medium allowing for fewer transmissions or shorter transmissions.