**IEEE P802.15**

**Wireless Personal Area Networks**

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| Project | IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs) | |
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| Re: | [TG10 TGD] | |
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| Purpose | [Sub-document of TGD] | |
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# Overview

# Definitions

# Abbreviation and acronyms

# General requirements

Use information from MAC and PHY Layer to inform flow control and routing. This differs from route-over where flow control is derived from information at Layer 3.

Will not alter the PHY or MAC functionality. The addition of Information Elements to facilitate the exchange of PHY and MAC information may be considered.

Support for multi-hop networks in linear topology for greatest range. Using 802.15.4g for one-to-many and many-to-one topologies. Supporting monitoring applications, with low duty cycle.

Support for commercial building automation, interior lighting control, street light control, and similar applications. These applications have requirements for peer to peer topology (switches or sensors to lights). Many-to-one and one-to-many relationships are required, as well as multicast to support groups of lights. Linear topology is also required for strings of lights. There is sometimes a requirement for mobility to support hand-held controls. There is a requirement for relatively low latency (100mS) for direct manual control of lights. This must be accomplished while maintaining low energy consumption. MAC functionality first defined in 802.15.4e as well as 6TISCH may be applicable. Gateways to building management systems (possibly using 802.3 or 802.11) may be required.

## Summary of PAR

### Scope

This recommended practice identifies protocols that route packets in a dynamically changing 802.15.4 network (changes on the order of a minute time frame), with minimal impact to route handling. The result is an extension of the area of coverage as the number of nodes increase.

### Purpose

This recommended practice facilitates the routing of packets in dynamically changing wireless networks. Specifically it provides for automatic handling of route related capabilities such as:

* Route establishment
* Dynamic route reconfiguration
  + Discovery and addition of new nodes
  + Breaking of established routes
  + Loss and recurrence of routes
* Real time gathering of link status
* Allowing for single hop appearance at the networking layer (not breaking standard L3 mechanisms)
* Support of broadcast
* Support of multicast
* Effective frame forwarding

## High level requirements

* One-to-many and many-to-one topologies

Support for multiple “concentrator” or gateway functions at the edge

Support large numbers of hops

Support for pre-described routes

Support for route diversity

Support scalability for large networks

Multicast support

* Support for device mobility within the network

Quick Rejoin Capability/Mechanism

* Flow control and routing functions, including congestion management and prioritization (message or path) are able to function using only information from MAC and PHY Layer services. Use of information from other layers is not precluded.

Support for route optimization and stale node purging

* Support for round trip delays through the entire network exceeding 2 seconds.
* Routing and networking functionality are scalable to operate on devices with limited memory and processing capability.
* Support for routing and network formation implemented in a distributed manner. This does not preclude source routing. Support for storing and non-storing nodes.
* Support for operation with minimal energy consumption and low (RF) power devices

Multicast support

Support for “sleepy nodes”, “sleepy routers”, and low duty cycle routers

* Security Aspects

Must be able to work w/just MAC layer security and compatible w/ KMP (including 802.1x, etc.) mechanisms - (Bob M.)

Joining Control

Quick Rejoin Capability/Mechanism

## Requirements from Proposed Applications

* Smart Metering (HAN and NAN)

The NIST Knowledgebase defines the metering use case as follows:

“Advanced metering infrastructure (AMI): Currently, utilities are focusing on developing AMI to implement residential demand response and to serve as the chief mechanism for implementing dynamic pricing. It consists of the communications hardware and software and associated system and data management software that creates a two-way network between advanced meters and utility business systems, enabling collection and distribution of information to customers and other parties, such as competitive retail suppliers or the utility itself. AMI provides customers real-time (or near real-time) pricing of electricity and it can help utilities achieve necessary load reductions.”

AMI (Smart Meter) use cases include (see doc. # 15-13-0564-01-0010 for details):

* **A Bulk Meter Readings**
* **On Demand Meter Reading from CIS**
* **Remote Programming of Smart Meter**
* **Remote Meter Firmware Update**
* **Meter Remote Connect Disconnect**
* **Outage Notification**
* **Outage Restoration Notification**
* **Real Time Price HAN Messaging**
* **Last Gasp Message**
* **Direct Load Control Event**
* **DR HAN Pricing & Event Customer Opt-Out**
* **AMI Network**
* **DR HAN Device Provisioning**
* **Plug In Electric Vehicle (PEV) Charging at Premise**



* Smart City (Street Lighting/Parking/Meters..) (see doc. # 15-13-0562-04-0010, and # 15-13-0703-00-0010 for details)

A smart city is considered as one which improves the quality of life of people by leveraging modern communication infrastructure and sustainable economic development. Wireless sensor networks are considered a specific technology to help to create smart cities.

Smart City use cases include:

* **Traffic System**
  + **Traffic Signal Control**
  + **Parking Guidance System**
  + **Street Light Control**
  + **Real Time Traffic Messaging (board or in car)**
* **Environment Monitoring**
  + **Pollution Monitoring**
  + **Noise Mapping**
  + **Disaster Notification**
* **Municipal Administration**
  + **Water Leak Detection**
  + **Garbage Collection System**
* **Structure Monitoring** 
  + **Bridge Monitoring**
  + **Tunnel Monitoring**
  + **Building Monitoring**
* **Irrigation Optimization**
  + **Park Management**
  + **Smart Agriculture**
* **CEMS, BEMS, HEMS (City, Building, Home Energy Management Systems)**
  + **Sustainable Subsistence System**
* **Smart Lighting**
  + **Intelligent Use for Energy Saving**
  + **Control for Personal Use**
  + **Control for Commercial Use**



* Requirements

This recommended practice will facilitate the routing of packets in dynamically changing wireless networks.

Facilitating:

* (Dynamic) Address network changes on the order of a minute time frame
* Minimizes impact to route handling

Specifically it will provide for automatic handling of route related capabilities such as:

* Route establishment and continuity
  + Effective frame forwarding
    - Priority vs. sphere of relevance (right size fit for the priority level)
  + Impact of maintaining security (don’t break it)
    - Impacts on provisioning, joining
* Dynamic route reconfiguration
  + Discovery and addition of new nodes
  + Breaking of established routes
  + Loss and recurrence of routes
  + Pruning of routes
  + Restart of network
* Route determination metrics and real time gathering of link status (Policy & Metrics)
  + Intra
    - * + Quality of individual hop
        + Quality of end-to-end route

Reduction of end-to-end retransmissions

* + - * + Latency
        + Data rate/multi-hop end-to-end route time
        + Resources (constraints)
  + Inter workings
    - * + Reported to system management

Persistent/consistent issues

Node outage (failure detection)

* + - * + Respond to system management feedback
* Support scalability
  + Node density, network size etc.
  + Hardware resource requirements
  + Behavior at restarts
  + Secondary, tertiary route considerations
  + Scalability of # takeout points - bridges to connecting networks (take out points)
* Management of flooding, multicasts
  + Support of broadcast
  + Support of (efficient) multicast
* Allowing for single hop appearance at the networking layer  
  (not breaking standard L3 mechanisms)
* Multiple route approaches within a network, possibilities include:
  + Concentric based
  + Linear (highway based)
  + Function /behavior/ priority based

## Defined Behaviors Should Support the Following in 802.15.4

* 802.15.4 2006 and forward
* Non-beacon networks
* Information Elements (not necc. all of them)
* TSCH
* CSL, RIT
* TMCTP
* Which PHYS
* Not 15.4J, 15.4F
* Between PHYS - consider for now

# Functional requirements

## Mesh Topology Discovery

## Mesh Routing Protocol

## Extensible Mesh Routing Architecture

## Mesh Broadcast Data Delivery

## Mesh Unicast Data Delivery

## Mesh Network Size

## Mesh Security

## Routing Metrics

### Radio-Aware

### Device-Aware

### Network-Aware

### Bridge-Aware

## Discovery and Association with a L2R network

## Changes to the MAC and PHY

# Performance requirements

# Required memory resource

## Calculation cost

## Energy consumption

## Control traffic overhead

## Route acquisition time

## Recovery time of link failure

## Scalability to network size

## End to End packet loss rate

## End to End data throughput and delay

## Life time of battery operated network

# Regulatory Considerations/Aspects

# Evaluation methodology