**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] | |
| Abstract | [Working document] | |
| Purpose | [see Re:] | |
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1. Overview

The intended use cases for the 802.15.10 Layer 2 Routing amendment diverge from the design assumptions of 802.1 bridging.

One example is the design philosophy of low-energy, constrained resource network devices that are generally seen in the 802.15.4 family. Low power is implemented in these ways: 1) Low data rates resulting from relatively simple radio physical layers. 2) MAC layer design to optimize for very low duty cycle operation and extended sleep time.

The combination of these two principles with a multi-hop topology can result in significant delays in forwarding a frame through multiple nodes in a network. Data rates in 802.15.4 range from less than 1 Kbps to over 27 Mbps. In some 802.15.4 PHYs, packet lengths up to 2047 octets are supported, along with data rates in the low kbps range. Transmitting a maximal length packet at the minimum rate would require over 1 S. Even when more practical packet lengths and data rates are considered, the additional delays for synchronizing sleep cycles and multiple hops could easily result in end-to-end delays exceeding several seconds.

This upper bound on packet delivery through the bridged network exceeds the design expectations of 802.1, which call for end-to-end reply within 2 S.

The possibility of delays exceeding 2 S will need to be considered as existing bridging mechanisms specified in 802.1 are considered for application in 802.15.10.

Due to the limited bandwidth of 802.15 networks, the use of broadcast and multicast for establishment and maintenance of bridging operation should be carefully considered, and minimized when possible.

1. Definitions
2. Abbreviation and acronyms
3. 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.

* 1. 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
  1. 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

* 1. Application requirements matrix
  2. 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

1. Functional requirements
   1. Mesh Topology Discovery

The proposal shall enable automatic topology learning, including the status and quality of links between devices.

* 1. Mesh Routing Protocol

MAC address-based protocol and algorithm shall be defined for dynamic auto-configuration of MAC-layer data delivery paths between devices in L2R network. Which path between devices should be established is up to network topology.

* 1. Extensible Mesh Routing Architecture

The proposal shall define protocol architecture to allow for alternative path selection metrics and/or routing protocols based on application requirements so that each device can detect which alternatives can be used or which alternative is currently used by other devices.

* 1. Mesh Broadcast Data Delivery

The proposal shall enable MAC-layer broadcast/multicast data delivery across the L2R network.

* 1. Mesh Unicast Data Delivery

The proposal shall enable MAC-layer unicast data delivery across the L2R network.

* 1. Mesh Network Size

The proposal shall support 1000-10000 devices in the L2R network.

* 1. Mesh Security
  2. Routing Metrics
     1. Radio-Aware
* At least one radio-aware routing metric shall be defined for use by the routing protocol(s).
* Multi PHY interfaces
  + 1. Device-Aware
* Energy constraints
* Memory constraints
  + 1. Network-Aware
* Optional upper layer information
  + 1. Bridge-Aware
* To networks using other standards (802.11, 802.1…)
  1. Discovery and Association with a L2R network

The proposal shall support the discovery of and association with a L2R network by devices.

* 1. Changes to the MAC and PHY

The proposal shall not require modifications to the 802.15.4 PHY or MAC layers with the exception of additional Information Elements to facilitate the exchange of PHY and MAC information.

1. Performance requirements
   1. Required memory resource.
   2. Calculation cost
   3. Energy consumption
   4. Control traffic overhead
   5. Route acquisition time
   6. Recovery time of link failure
   7. Scalability to network size
   8. End to End packet loss rate
   9. End to End data throughput and delay
   10. Life time of battery operated network
2. Regulatory Considerations/Aspects
3. Evaluation methodology