6TiSCH
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Terminology in IPv6 over the TSCH mode of IEEE 802.15.4e
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Abstract

6TiSCH proposes an architecture for an IPv6 multi-link subnet that is composed of a high speed powered backbone and a number of IEEE802.15.4e TSCH wireless networks attached and synchronized by backbone routers. This document extends existing terminology documents available for Low-power and Lossy Networks to provide additional terminology elements.

Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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1. Introduction

The IEEE802.15.4 Medium Access Control (MAC) has evolved with IEEE802.15.4e which provides in particular the Time Slotted Channel Hopping (TSCH) mode for industrial-type applications. It provides deterministic capabilities to the point that a packet that pertains to a certain flow crosses the network from node to node following a very precise schedule, like a train leaves intermediate stations at precise times along its path.

This document provides additional terminology elements to cover terms that are new to the context of TSCH wireless networks and other deterministic networks.

2. Terminology

The draft extends [I-D.ietf-roll-terminology] and use terms from RFC 6550 [RFC6550] and RFC 6552 [RFC6552], which are all included here by reference.

The draft does not reuse terms from IEEE802.15.4e such as "path" or "link" which bear a meaning that is quite different from classical IETF parlance.

This document adds the following terms:

6TiSCH: IPv6 over the Timeslotted Channel Hopping (TSCH) mode of IEEE802.15.4e. It defines (i)the 6top sublayer; (ii) a set of protocols for setting up a TSCH schedule with a centralized and/or distributed approach, for managing the allocation of resources; and (iii) the architecture to bind them together, for use in IPv6 TSCH based networks.

6F: IPv6 Forwarding. One of the three forwarding models supported by 6TiSCH. Packets are routed at layer 3, where Quality of Service (QoS) and Active Queue Management (e.g., Random Early Detection, RED, [RFC2309]) operations are expected to prioritize flows with differentiated services.

6top: 6top is the adaptation sublayer between TSCH and upper layers like IPv6 over Low-Power Wireless Personal Area Networks (6LoWPANs) and IPv6 Routing Protocol for Low-Power and Lossy Networks (RPL). It is defined in [I-D.wang-6tisch-6top-sublayer].

6top Data Convey Model: Model describing how the 6top adaptation layer feeds the data flow coming from upper layers into TSCH. It is composed by an I-MUX module, a MUX module, a set of priority queues, and a PDU (Payload Data Unit). See [I-D.wang-6tisch-6top-sublayer].

ARO: [RFC6775] defines a number of new Neighbor Discovery options including the Address Registration Option (ARO).

ASN: Absolute Slot Number, the total number of timeslots that

has elapsed since the PAN coordinator has started the TSCH network. It is incremented by one at each timeslot. It is wide enough to not roll over in practice. See [IEEE802154e].

Blacklist of Frequencies: Simply defined Blacklist in [IEEE802154e], it is the set of frequencies among the 16 available ones, which should not be used for communication.

BBR: Backbone Router. In the 6TiSCH architecture, it is an LBR and also a IPv6 ND-efficiency-aware Router (NEAR) [I-D.chakrabarti-nordmark-6man-efficient-nd]. It

performs ND proxy operations between registered devices and classical ND devices that are located over the backbone.

Broadcast Cell: A scheduled cell used for broadcast transmission.

Bundle: A group of equivalent scheduled cells, i.e. cells identified by different [slotOffset, channelOffset], which are scheduled for a same purpose, with the same neighbor, with the same flags, and the same slotframe. The size of the bundle refers to the number of cells it contains. Given the length of the slotframe, the size of the bundle translates directly into bandwidth. A bundle represents a half-duplex link between nodes, one transmitter and one or more receivers, with a bandwidth that amount to the sum of the cells in the bundle. A bundle is globally identified by (source MAC, destination MAC, TrackID). At Layer 3 a pair of bundles forms a link. By usining a well-known constant, NULLT, as TrackId for a L3 link, the IP link between adjacent nodes A and B comprises 2 bundles: (macA, macB, NULLT) and (macB, macA, NULLT). At L2 a pair of bundles forms a switching state. Considered a segment A-B-C along a track, there are two bundles in node B, one incoming = (macA, macB, trackId) and one outgoing = (macB, macC, trackId).

Cell: A single element in the TSCH schedule, identified by a slotOffset, a channelOffset, a slotframeHandle. A cell

can be scheduled or unscheduled.

Centralized Cell Reservation: A reservation of a cell done by a centralized entity (e.g., a PCE) in the network.

Centralized Track Reservation: A reservation of a track done by a centralized entity (e.g., a PCE) in the network.

ChannelOffset: Identifies a row in the TSCH schedule. The number of available channelOffsets is equal to the number of available frequencies. The channelOffset translates into a frequency when the communication takes place, resulting in channel hopping, as detailed in [RFC7554].

Channel Distribution/Usage (CDU) matrix: : Matrix of cells (i,j) representing the spectrum (channel) distribution among the different nodes in the 6TiSCH network. The CDU matrix has width in timeslots, equal to the period of the network scheduling operation, and height equal to the

number of available channels. Every cell (i,j) in the CDU, identified by (slotOffset, channelOffset), belongs to a specific chunk. It has to be noticed that such a matrix which includes all the cells grouped in chunks, belonging to different slotframes, is different from the TSCH schedule.

Chunk: A well-known list of cells, distributed in time and frequency, within a CDU matrix; a chunk represents a portion of a CDU matrix. The partition of the CDU in chunks is globally known by all the nodes in the network to support the appropriation process, which is a negotiation between nodes within an interference domain. A node that manages to appropriate a chunk gets to decide which transmissions will occur over the cells in the chunk within its interference domain (i.e., a parent node will decide when the cells within the appropriated chunk are used and by which node, among its children.

Communication Paradigm: It is Associated with the Information Model [RFC3444] of the state that is exchanged, and indicates: the location of that state (e.g., centralized vs.

distributed, RESTful, etc.), the numbers of parties (e.g., point to point, P2P, vs. point to multi-point, P2MP) and the relationship between parties (e.g., master/slave vs. peers) at a high level of protocol abstraction. Layer 5 client/server REST is a typical communication paradigm, but industrial protocols also use publish/subscribe which is P2MP and source/sink which is multi-point to multi-point (MP2MP) and primarily used for alarms and alerts at the application layer. At layer 3, basic flooding, P2P synchronization and path-marking (RSVP-like) are commonly used paradigms, whereas at layer 2, master/slave polling and peer-to-peer forwarding are classical examples.

DAR/DAC: [RFC6775] defines the Duplicate Address Request (DAR) and Duplicate Address Confirmation (DAC) options to turn the multicast Duplicate Address Detection protocol into a unicast-based multi-hop process between routers and the backbone router.

Dedicated Cell: A cell that is reserved for a given node to transmit to a specific neighbor.

Deterministic Network: A Deterministic Network supports traffic flows with communication patterns that are known a priori. Thus, routing paths and communication schedules

can be computed in advance, in a fashion similar to a railway system, to avoid losses due to packet collisions, and to perform global optimizations across multiple flows. A deterministic network can allocates the required resources (buffers, processors, medium access) along the multi-hop routing path at the precise moment the resources are needed.

Distributed Cell Reservation: A reservation of a cell done by one or more in-network entities (typically a connection endpoint).

Distributed Track Reservation: A reservation of a track done by one or more in-network entities (typically a connection endpoint).

EARO: [I-D.thubert-6lo-rfc6775-update-reqs] extends the ARO option to include some additional fields necessary to distinguish duplicate addresses from nodes that have moved networks when there are mulitple LLNs linked over a backbone.

EB: Enhanced Beacon frame used by a node to announce the presence of the network. It contains useful information (see [IEEE802154e] for details) that allow a new node to synhronize and join the network.

FF: 6LoWPAN Fragment Forwarding. It is one of the three forwarding models supported by 6TiSCH. The 6LoWPAN Fragment is used as a label for switching at the 6LoWPAN sublayer, as defined in [I-D.thubert-roll-forwarding-frags].

GMPLS: Generalized Multi-Protocol Label Switching, a 2.5 layer service that is used to forward packets based on the concept of generalized labels.

Hard Cell: A scheduled cell which the 6top sublayer cannot reallocate. See [I-D.wang-6tisch-6top-sublayer].

Hopping Sequence: Ordered sequence of frequencies, identified by a Hopping_Sequence_ID, used for channel hopping, when translating the channel offset value into a frequency (i.e., PHY channel). See [IEEE802154e] and [RFC7554].

IE: Information Elements, a list of Type-Length-Value containers placed at the end of the MAC header, used to pass data between layers or devices. A small number of

types are defined by [IEEE802154e], but a range of types is available for extensions, and thus, is exploitable by 6TiSCH. See [IEEE802154e].

I-MUX module: Inverse-Multiplexer, a classifier that receives 6LoWPAN frames and places them into priority queues. See [I-D.wang-6tisch-6top-sublayer].

Interaction Model: It is a particular way of implementing a communication paradigm. Defined at a lower level of abstraction, it includes protocol-specific details such as a particular method (e.g., a REST GET) and a Data Model for the state to be exchanged.

Interference Domain: The Interference Domain of a given (transmitter) node A includes all the nodes in its neighbourhood that can generate interference at its receiver B, when transmitting on the same channel (i.e., using the same frequency).

JCE: The Join Coordination Entity (JCE) is a central entity like the Path Computation Element (PCE), that may assist in several aspects of the join protocol, such as authentication, authorization, and configuration.

JA: The Join Assistant (JA) is a one-hop neighbor of a joining node that may facilitate it to become meaningful part of the network (e.g., by serving as a local connectivity point to the remainder of the network).

Join Protocol: The protocol which secures initial communication between a joining node and the JCE.

LBR: Low-power Lossy Network (LLN) Border Router. It is an LLN device, usually powered, that acts as a Border Router to the outside within the 6TiSCH architecture.

Link: A communication facility or medium over which nodes can communicate at the link layer, i.e., the layer immediately below IP. Thus, the IETF parlance for the term "Link" is adopted, as opposed to the IEEE802.15.4e terminology. In the context of the 6TiSCH architecture, which applies to Low Power Lossy Networks (LLNs), an IPv6 subnet is usually not congruent to a single link and techniques such as IPv6 Neighbor Discovery Proxying are used to achieve reachability within the multilink subnet. A link is distinct from a track. In fact, link local addresses are not expected to be used over a track for

end to end communication. Finally, from the Layer 3

perspective (where the inner complexities of TSCH operations are hidden to enable classical IP routing and forwarding), a single radio interface may be seen as a number of Links with different capabilities for unicast or multicast services.

MAC: Medium Access Control.

MUX Module: Multiplexer, the entity that dequeues frames from priority queues and associates them to a cell for transmission. See [I-D.wang-6tisch-6top-sublayer].

NEAR: IPv6 ND-efficiency-aware Router, as defined in [I-D.chakrabarti-nordmark-6man-efficient-nd].

NME: Network Management Entity, the entity in the network managing cells and other device resources. It may cooperate with the PCE. It interacts with LLN nodes through the backbone router.

Operational Network: A IEEE802.15.4e network whose encryption/ authentication keys are determined by some algorithms/ protocols. There may be network-wide group keys, or per-link keys.

Operational Network Key: A Link-layer key known by all authorized nodes, used for multicast messages.

PCE: Path Computation Element, the entity in the network which is responsible for building and maintaining the TSCH schedule, when centralized scheduling is used.

QoS: Quality of Service.

(to) Reallocate a Cell: The action operated by the 6top sublayer of changing the slotOffset and/or channelOffset of a soft cell.

(to) Schedule a Cell: The action of turning an unscheduled cell into a scheduled cell.

Scheduled cell: A cell which is assigned a neighbor MAC address (broadcast address is also possible), and one or more of the following flags: TX, RX, shared, timeskeeping. A scheduled cell can be used by the IEEE802.15.4e TSCH implementation to communicate. A scheduled cell can be either a hard or a soft cell.

Shared Cell: A cell marked with both the "TX" and "shared" flags. This cell can be used by more than one transmitter node. A backoff algorithm is used to resolve contention. See [RFC7554].

SlotOffset: Identifies a column in the TSCH schedule, i.e., the number of timeslots since the beginning of the current iteration of the slotframe.

Slotframe: A MAC-level abstraction that is internal to the node and contains a series of timeslots of equal length and priority. It is characterized by a slotframe_ID, and a slotframe_size. Multiple slotframes can coexist in a node's schedule, i.e., a node can have multiple activities scheduled in different slotframes, based on the priority of its packets/traffic flows. The timeslots in the Slotframe are indexed by the SlotOffset; the first timeslot is at SlotOffset 0.

Soft Cell: A scheduled cell which the 6top sublayer can reallocate, as described in [I-D.wang-6tisch-6top-sublayer].

TF: Track Forwarding. It is the simplest and fastest forwarding model supported by 6TiSCH. It is a GMPLS-like forwarding model. The incoming bundle (and thus, the input cell) characterizes the flow and indicates the outgoing bundle (and output cell).

Timeslot: A basic communication unit in TSCH which allows a transmitter node to send a frame to a receiver neighbor, and that receiver neighbor to optionally send back an acknowledgment.

Time Source Neighbor: A neighbor that a node uses as its time reference, and to which it needs to keep its clock synchronized. A node can have one or more time source neighbors.

Track: A determined sequence of cells along a multi-hop path. It is typically the result of a track reservation. The node that initializes the process for establishing a track is the owner of the track. The latter assigns a unique identifier to the track, called TrackID.

TrackID: Unique identifier of a track, assigned by the owner of the track.

TSCH: Time Slotted Channel Hopping, a medium access mode of the [IEEE802154e] standard which uses time synchronization to achieve ultra low-power operation and channel hopping to enable high reliability.

TSCH Schedule: A matrix of cells, each cell indexed by a slotOffset and a channelOffset. The TSCH schedule contains all the scheduled cells from all slotframes and is sufficient to qualify the communication in the TSCH network. The "width of the matrix is equal to the number of scheduled timeslots in all the concurrent active slotframes. The number of channelOffset values (the "height" of the matrix) is equal to the number of available frequencies.

Unscheduled Cell: A cell which is not used by the IEEE802.15.4e TSCH implementation.

3. IANA Considerations

This specification does not require IANA action.

4. Security Considerations

This specification is not found to introduce new security threats.

5. Acknowledgments

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