6TiSCH
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MR. Palattella, Ed.
SnT/Univ. of Luxembourg
P. Thubert
cisco
T. Watteyne
Linear Technology / Dust Networks
Q. Wang
Univ. of Sci. and Tech. Beijing
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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 multilink 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

A new breed of Time Sensitive Networks is being developed to enable traffic that is highly sensitive to jitter and quite sensitive to latency. Such traffic is not limited to voice and video, but also includes command and control operations such as in industrial automation or in-vehicle sensors and actuators.

At IEEE802.1, the "Audio/Video Task Group", was renamed TSN for Time Sensitive Networking. 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. Both provide 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 IEEE 802.15.4e. It defines a set of IETF sublayers and protocols (in particular, for setting up a schedule with a centralized or distributed approach, managing the resource allocation), as well as the architecture to bind them together, for use in IPv6 TSCH based networks.

6F: IPv6 Forwarding. One of the three forwarding model supported by 6TiSCH. Packets are routed at layer 3, where QoS and RED operations are expected to prioritize flows with differentiated services.

6top: 6top is the adaptation layer between TSCH and upper layers like 6LoWPAN and RPL. It is defined in [I-D.draft-wang-6tsch-6top].

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).

ASN: Absolute Slot Number, the timeslot counter, incremented by one at each timeslot. It is wide enough to not roll over in practice. See [I-D.watteyne-6tsch-tsch-lln-context].

Blacklist: Set of frequencies which should not be used for communication.

BBR: Backbone Router. In the 6TiSCH architecture, it is an LBR and also a NEAR. It performs ND proxy operations between registered devices and classical ND devices that are located over the backbone.

Broadcast cell: A scheduled cell whose neighbor MAC address is set to the broadcast address.

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, either logical, or physical.

Cell: A single element in the TSCH schedule, identified by a slotOffset, a channelOffset, a slotframeHandle. A cell can be scheduled or unscheduled.

ChannelOffset: Identifies a row in the TSCH slotframe. 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 [I-D.watteyne-6tsch-tsch-lln-context].

Channel distribution/usage (CDU) matrix: : Matrix of height equal to the number of available channels (i.e, ChannelOffsets), representing the spectrum(channel) distribution among the different (RPL parent) nodes in the networks. Every single element of the matrix belongs to a specific chunk. It has to be noticed that such matrix, even though it includes all the cells grouped in chunks, belonging to different slotframes, is different from the TSCH schedule.

Chunk: A well-known list of cells, well-distributed in time and frequency, within a slotframe; a chunk represents a portion of a slotframe that is globally known by all the nodes in the network, but it can be managed separately by a single node. A node can have multiple chunks, and use them according to a specific policy. Chunks may overlap. They can be pre-programmed, or can be computed by an external entity at the network bootstrap.

Chunk ownership appropriation: The process by which an individual node obtains a chunk to manage based on peer-to-peer interaction with its neighbors.

Chunk ownership delegation: The process by which an individual node obtains a chunk to manage based on point-to-point interaction with an external entity.

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., P2P vs. 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 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.

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

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).

EB: Enhanced Beacon frame used by an advertising node to announce the presence of the network. It contains information about the timeslot length, the current ASN value, the slotframes and timeslots the beaconing mote is listening on, and a 1-byte join priority (i.e., number of hops separating the node sending the EB, and the PAN coordinator).

FF: 6LoWPAN Fragment Forwarding. It is one of the three forwarding model 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.draft-wang-6tsch-6top].

Hopping Sequence: 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 [I-D.watteyne-6tsch-tsch-lln-context].

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 TSCH, but a range of types is available for extensions, and thus, is exploitable by 6TiSCH. See [I-D.watteyne-6tsch-tsch-lln-context].

I-MUX module: Inverse-Multiplexer, a classifier that receives 6LoWPAN frames and places them into priority queues.

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.

KMP: Key Managment Protocol.

LBR: 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 incompatible 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 and Routing Over LLNs are required 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.

Logical Cell: A cell that corresponds to granted bandwidth but is only lazily associated to a physical cell, based on usage.

MAC: Medium Access Control.

MUX module: Multiplexer, the entity that dequeues frames from priority queues and associates them to a cell for transmission.

NEAR: Energy Aware Default 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.

PANA: Protocol for carrying Authentication for Network Access, as defined in [RFC5191] . It is the protocol used in the 6TiSCH architecture for handling authentication during the join process.

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

PCE cell reservation: The reservation of a cell done by the PCE.

PCE track reservation: The reservation of a track done by the PCE.

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.

SA: Security Association.

(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 a hard cell or a soft cell.

Shared Cell: A cell that is used by more than one transmitter nodes at the same time and on the same channelOffset. Only cells with TX flag can be marked as "shared". A backoff algorithm is used to resolve contention.

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.draft-wang-6tsch-6top].

TF: Track Forwarding. It is the simplest and fastest forwarding model supported by 6TiSCH. It is a G-MPLS-like forwarding model. The input cell characterises the flow and indicates the 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. The length of the timeslot determines the maximum size of the frame that can be exchanged.

Time Source Neighbor: A neighbor 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 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 slotframe size (the "width" of the matrix) is the number of timeslots it contains. The number of channelOffset values (the "height" of the matrix) is equal to the number of available frequencies. The TSCH schedule contains all the scheduled cells from all slotframes and is sufficient to qualify the communication in the TSCH network.

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 threat.

5. Acknowledgements

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6.1. Normative References

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Authors' Addresses

Maria Rita Palattella (editor)
University of Luxembourg
Interdisciplinary Centre for Security, Reliability and Trust
4, rue Alphonse Weicker
Luxembourg L-2721
LUXEMBOURG

Phone: (+352) 46 66 44 5841
Email: maria-rita.palattella@uni.lu

Pascal Thubert
Cisco Systems, Inc
Village d'Entreprises Green Side
400, Avenue de Roumanille
Batiment T3
Biot - Sophia Antipolis 06410
FRANCE

Phone: +33 497 23 26 34
Email: pthubert@cisco.com

Thomas Watteyne
Linear Technology / Dust Networks
30695 Huntwood Avenue
Hayward, CA 94544
USA

Phone: +1 (510) 400-2978
Email: twatteyne@linear.com

Qin Wang
Univ. of Sci. and Tech. Beijing
30 Xueyuan Road
Beijing, Hebei 100083
China

Phone: +86 (10) 6233 4781
Email: wangqin@ies.ustb.edu.cn