

6TiSCH  
Internet-Draft  
Intended status: Informational  
Expires: November 13, 2016

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May 12, 2016

6TiSCH 6top Scheduling Function Zero (SF0)  
[draft-ietf-6tisch-6top-sf0-00](#)

## Abstract

This document defines a 6top Scheduling Function called "Scheduling Function Zero" (SF0). SF0 dynamically adapts the number of reserved cells between neighbor nodes, based on the currently allocated bandwidth and the neighbour nodes' requirements. Neighbor nodes negotiate in a distributed neighbor-to-neighbor basis the cell(s) to be added/deleted. SF0 uses the 6P signaling messages to add/delete cells in the schedule. Some basic rules for deciding when to add/delete cells and for selecting the cells to be added/deleted within the schedule are also provided.

## 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].

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Internet-Draft

6tisch-6top-sf0

May 2016

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## [1.](#) Introduction

This document defines the Scheduling Function for the 6top sublayer [[I-D.wang-6tisch-6top-sublayer](#)] called "Scheduling Function Zero" (SF0).

This document addresses the requirements for a scheduling function listed in [[I-D.wang-6tisch-6top-sublayer](#)], Section 4.2, and follows the recommended outline from [Section 4.3](#).

## [2.](#) Scheduling Function Identifier

The Scheduling Function Identifier (SFID) of SF0 is IANA\_SFID\_SF0.

## [3.](#) Rules for Adding/Deleting Cells

A node running SF0 determines when to add/delete cells in a three-step process:

1. It waits for a triggering event ([Section 3.1](#)).
2. It applies the Bandwidth Estimation Algorithm (BEA) for a particular neighbor to determine how much bandwidth is required to that neighbor ([Section 3.2](#)).
3. It applies the Allocation Policy to compare the number of required cells to the number of already scheduled cells, and determine the number of cells to add/delete ([Section 3.3](#)).

### [3.1.](#) SF0 Triggering Events

We RECOMMEND SF0 to be triggered at least by the following events:

1. If the Remaining Available Bandwidth (RAB) is less than the Minimum Remaining Bandwidth (MRB)
2. If there is any New Incoming Bandwidth Requirements from neighbour nodes (NIBR)

This allows SF0 to be triggered by any change in local node bandwidth and/or incoming bandwidth. The exact mechanism of when SF0 is triggered is implementation-specific.

### [3.2.](#) SF0 Bandwidth Estimation Algorithm

The Bandwidth Estimation Algorithm takes into account the sum of the incoming bandwidth requirements from the neighbour nodes and the used outgoing bandwidth. This allows the node to estimate the total outgoing bandwidth requirement. As a consequence, the Bandwidth Estimation Algorithm for SF0 follows the steps described below:

1. Collect the New Incoming Bandwidth Requirements from neighbour nodes (NIBR)
2. Obtain the Current Outgoing Bandwidth Usage (COBU)
3. Obtain the number of Current Scheduled Bandwidth (CSB)
4. Calculate the New Outgoing Bandwidth (NOB) as:  $NOB = COBU + NIBR$
5. Calculate the Remaining Available Bandwidth (RAB) as  $RAB = CSB - NOB$

6. If the RAB is less than the Minimum Remaining Bandwidth (MRB), Add MRB to the NOB:  $NOB = NOB + MRB$
7. Submit the request to the allocation policy
8. Return to step 1 and wait for a triggering event.

### [3.3.](#) SF0 Allocation Policy

The "Allocation Policy" is the set of rules used by SF0 to decide when to add/delete cells to a particular neighbor to satisfy the bandwidth requirements.

SF0 uses the following parameters:

**SCHEDULEDCELLS:** The number of cells scheduled from the current node to a particular neighbor.

**REQUIREDCELLS:** The number of cells calculated by the Bandwidth Estimation Algorithm from the current node to that neighbor.

**SF0THRESH:** Threshold parameter introducing cell over-provisioning in the allocation policy. It is a non-negative value expressed as number of cells. The definition of this value is implementation-specific; however, it is RECOMMENDED a SF0THRESH value of 3 cells. A setting of  $SF0THRESH > 0$  will cause the node to allocate at least SF0THRESH cells to each of its' neighbours.

The SF0 allocation policy compares REQUIREDCELLS with SCHEDULEDCELLS and decides to add/delete cells taking into account SF0THRESH. This is illustrated in Figure 1.

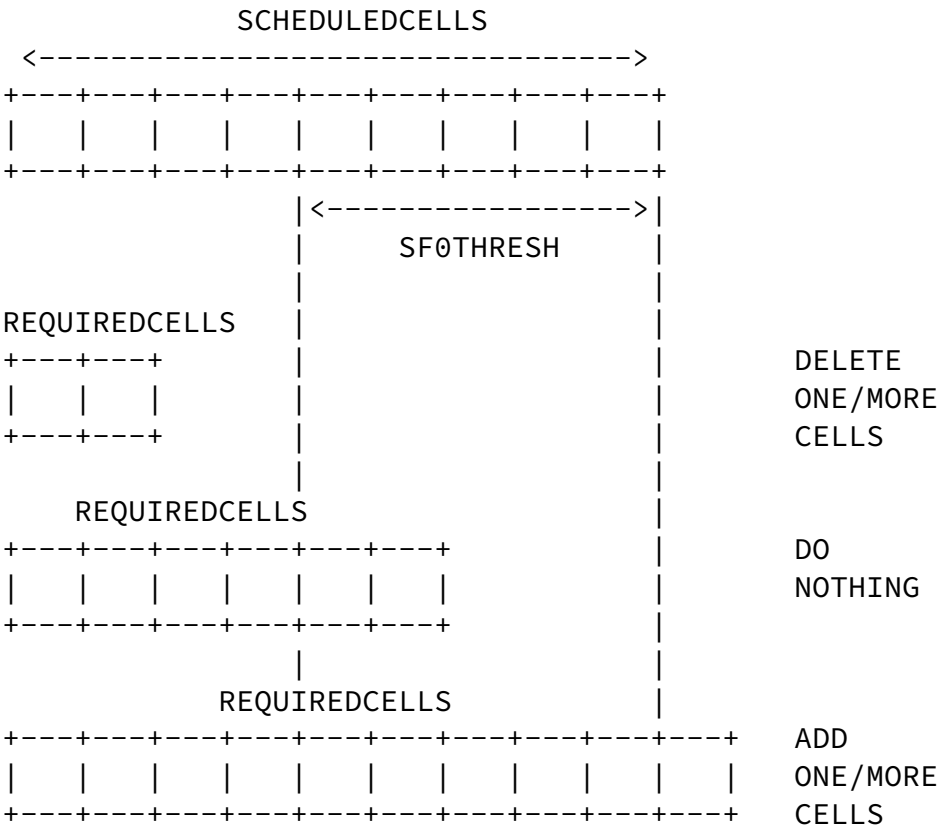


Figure 1: The SF0 Allocation Policy

1. If  $\text{REQUIREDCELLS} < (\text{SCHEDULEDCELLS} - \text{SF0THRESH})$ , delete one or more cells.
2. If  $(\text{SCHEDULEDCELLS} - \text{SF0THRESH}) \leq \text{REQUIREDCELLS} \leq \text{SCHEDULEDCELLS}$ , do nothing.
3. If  $\text{SCHEDULEDCELLS} \leq \text{REQUIREDCELLS}$ , add one or more cells.

When SF0THRESH equals 0, any discrepancy between REQUIREDCELLS and SCHEDULEDCELLS triggers an action to add/delete cells. Positive values of SF0THRESH reduce the number of 6P Transactions.

The Allocation Policy also translates the bandwidth requirement into cells according to their PDR. For example, if a cell with a 100% PDR is equivalent to 1Kbps, and the required bandwidth is 8Kbps, then, the number of scheduled cells will be 8. However, if two of the allocated cells have a 70% PDR, their number of scheduled cells will be 9.

#### [4.](#) Rules for CellList

When issuing a 6top ADD Request, SF0 executes the following sequence:

Whitelist case:

The Transaction Source node: Prepares the CellList field by selecting randomly the required cells, verifying that the slot offset and channel offset are not occupied.

The Transaction Destination node: Goes through the cells in the CellList in order, verifying whether there are no slotOffset conflicts.

Blacklist case:

The Transaction Source node: Prepares the CellList field by building a list of currently scheduled cells into the CellList.  
The Transaction Destination node: Selects randomly the required cells, verifying that the slot offset and channel offset are not occupied from the ones on the CellList.

#### [5.](#) 6P Timeout Value

The 6P Timeout Value provided by SF0 allows the maximum number of TSCH link-layer retries. Given the TSCH parameters for the backoff mechanism, macMinBE and macMaxBE, and the length in seconds of the minimal Slotframe, SM, the timeout value is computed as:  $\text{timeout} = (2^{(\text{macMaxBE}+1)} - 2^{\text{macMinBE}}) * \text{SM}$  TODO: Change general timeout to a timeout adapted to the schedule: SF to use the number of slots until the next scheduled cell.

## 6. Meaning of Metadata Information

The Metadata 16-bit field is used as follows:

BITS 0-7 [SLOTFRAME] are used to identify the slotframe number  
BITS 8-14 are RESERVED  
BIT 15 [WBLIST] is used to indicate that the CellList provided is a Whitelist (value=0) or a Blacklist (value=1).

TODO: length of the SlotFrame SHOULD be an integer multiple of the length of the minimal SlotFrame.

## 7. Node Behavior at Boot

In order to define a known state after the node is restarted, a CLEAR command is issued to each of the neighbour nodes to enable a new allocation process. TODO: Temporary cells from a pool for the join process.

## 8. Relocating Cells

SF0 uses Packet Delivery Rate (PDR) statistics to monitor the currently allocated cells for cell re-allocation (by changing their

slotOffset and/or channelOffset) when it finds out that the PDR of one or more softcells below 20% of the average PDR.

## 9. Forced Cell Deletion Policy

TODO: When all the cells are scheduled, we need a policy to free cells, for example, under alarm conditions or if a node disappears from the neighbour list.

## 10. 6P Error Handling

A node implementing SF0 handles a 6P Response depending on the Return Code it contains:

### RC\_SUCCESS:

If the number of elements in the CellList is the number of cells specified in the NumCells field of the 6P ALL Request, the operation is complete. The node does not take further action. If the number of elements in the CellList is smaller (possibly 0) than the number of cells specified in the NumCells field of the 6P ALL Request, the neighbor has received the request, but less than NumCells of the cells in the CellList were. In that case, the node MAY retry immediately with a different CellList if the amount of storage space permits, or build a new (random) CellList.

RC\_ERR\_VER: The node MUST NOT retry immediately. The node MAY add the neighbor node on a blacklist. The node MAY retry to contact this neighbor later.

RC\_ERR\_60FID: The node MUST NOT retry immediately. The node MAY add the neighbor node on a blacklist. The node MAY retry to contact this neighbor later.

RC\_ERR\_NORESOURCES: Wait for a timeout and restart the scheduling process.

RC\_ERR\_BUSY: Issue a RESET command.

## 11. Examples

TODO

## 12. Implementation Status

This section records the status of known implementations of the protocol defined by this specification at the time of posting of this Internet-Draft, and is based on a proposal described in [[RFC6982](#)]. The description of implementations in this section is intended to assist the IETF in its decision processes in progressing drafts to RFCs. Please note that the listing of any individual implementation here does not imply endorsement by the IETF. Furthermore, no effort has been spent to verify the information presented here that was



be construed to be, a catalog of available implementations or their features. Readers are advised to note that other implementations may exist.

According to [RFC6982], "this will allow reviewers and working groups to assign due consideration to documents that have the benefit of running code, which may serve as evidence of valuable experimentation and feedback that have made the implemented protocols more mature. It is up to the individual working groups to use this information as they see fit".

OpenWSN: This specification is implemented in the OpenWSN project [OpenWSN]. The authors of this document are collaborating with the OpenWSN community to gather feedback about the status and performance of the protocols described in this document. Results from that discussion will appear in this section in future revision of this specification.

### 13. Security Considerations

TODO

### 14. IANA Considerations

- o IANA\_SFID\_SF0

### 15. Acknowledgments

Thanks to Kris Pister for his contribution in designing the default Bandwidth Estimation Algorithm. Thanks to Qin Wang and Thomas Watteyne for their support in defining the interaction between SF0 and the 6top sublayer.

This work is partially supported by the Fondecyt 1121475 Project, the Inria-Chile "Network Design" group, and the IoT6 European Project (STREP) of the 7th Framework Program (Grant 288445).

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May 2016

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