6TiSCH   D. Dujovne, Ed.
Internet-Draft   Universidad Diego Portales
Intended status: Experimental   LA. Grieco
Expires: September 6, 2018   Politecnico di Bari
                                                    MR. Palattella
          Luxembourg Institute of Science and Technology (LIST)
                                                      N. Accettura
                                                         LAAS-CNRS
                                                     March 5, 2018

               6TiSCH Experimental Scheduling Function (SFX)
                      draft-ietf-6tisch-6top-sfx-01

Abstract

   This document defines a Scheduling Function called "Experimental
   Scheduling Function" (SFX). SFX dynamically adapts the number of
   scheduled cells between neighbor nodes, based on the amount of
   currently allocated cells and the neighbor nodes' cell requirements.
   Neighbor nodes negotiate in a distributed neighbor-to-neighbor basis
   the number of cell(s) to be added/deleted. SFX uses the 6P signaling
   messages to add/delete cells in the schedule. This function selects
   the candidate cells from the schedule, defines which cells will be
   added/deleted and triggers the allocation/deallocation process.

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.

   Internet-Drafts are working documents of the Internet Engineering
   Task Force (IETF). Note that other groups may also distribute
   working documents as Internet-Drafts. The list of current Internet-
   Drafts is at https://datatracker.ietf.org/drafts/current/.

   Internet-Drafts are draft documents valid for a maximum of six months
   and may be updated, replaced, or obsoleted by other documents at any
   time. It is inappropriate to use Internet-Drafts as reference
   material or to cite them other than as "work in progress."

   This Internet-Draft will expire on September 6, 2018.

Copyright Notice

Table of Contents

1. Introduction

   This document defines a Scheduling Function using the 6P protocol
   [I-D.ietf-6tisch-6top-protocol], called "Experimental Scheduling
   Function" (SFX). SFX is designed to offer a number of
   functionalities to be usable in a wide range of applications. SFX
   defines two algorithms: the Scheduling Algorithm which defines the
   number of cells to allocate/delete between two neighbors, and the
   Relocation Algorithm defines when to relocate a cell.

   To synthesize, a node running SFX determines when to add/delete cells
   in a three-step process:

   1. It waits for a triggering event (Section 5.1).
   2. It applies the Cell Estimation Algorithm (CEA) for a particular
       neighbor to determine how many cells are required to that
       neighbor (Section 5.2).
   3. It applies the Allocation Policy to compare the number of
       required cells to the number of already scheduled cells, and
       determines the number of cells to add/delete (Section 5.3).

   SFX addresses the requirements for a scheduling function listed in
   Section 5.2 from [I-D.ietf-6tisch-6top-protocol], and follows the
   recommended outline listed in Section 5.3 of
   [I-D.ietf-6tisch-6top-protocol]. This document follows the
   terminology defined in [I-D.ietf-6tisch-terminology].

2. Scheduling Function Identifier

   The Scheduling Function Identifier (SFID) of SFX is
   IANA_6TISCH_SFID_SFX.

3. Allocated and Used Cells

   An allocated cell is assigned as a TX, RX or Shared cell on the
   schedule, as a reserved resource. This reservation does not imply
   that a packet will be transmitted during the scheduled cell time. A
   used cell is a cell where a packet has been transmitted during the
   scheduled cell time on the last slotframe.

4. Overprovisioning

   Overprovisioning is the action and effect of increasing a value
   representing an amount of resources. In the case of SFX,
   overprovisioning is done as a provision to reduce traffic variability
   effects on packet loss, to the expense of artificially allocating a
   number of cells.

5. Scheduling Algorithm

   A number of TX cells must be allocated between neighbor nodes in
   order to enable data transmission among them. A portion of these
   allocated cells will be used by neighbors, while the remaining cells
   can be over-provisioned to handle unanticipated increases in cell
   requirements. The Scheduling Algorithm collects the cell allocation/
   deallocation requests from the neighbors and the number of cells
   which are currently under usage. First, the Cell Estimation
   Algorithm calculates the number of required cells and second, the
   calculated number is transferred to the Allocation Policy. In order
   to reduce consumption, this algorithm is triggered only when there is
   a change on the number of used cells from a particular node.

5.1. SFX Triggering Events

   We RECOMMEND SFX to be triggered by the following event: if there is
   a change on the number of used cells towards any of the neighbors.
   The exact mechanism of when SFX is triggered is implementation-
   specific.

5.2. SFX Cell Estimation Algorithm

   The Cell Estimation Algorithm takes into account the number of
   currently used cells to the neighbor. This allows the algorithm to
   estimate a new number of cells to be scheduled to the neighbor. As a
   consequence, the Cell Estimation Algorithm for SFX follows the steps
   described below:

   1. Collect the current number of used cells to the neighbor.
   2. Calculate the new number of cells to be scheduled to the neighbor
       by adding the current number of used cells plus an OVERPROVISION
       number of cells.
   3. Transfer the request to the allocation policy as REQUIREDCELLS.
   4. Return to step 1 and wait for a triggering event.

   The Cell Estimation Algorithm is depicted in Figure 1. The
   OVERPROVISION parameter is calculated as a percentage of the number
   of currently scheduled cells to the neighbor. OVERPROVISION is added
   to the amount of used cells to the neighbor to reduce the probability
   of packet loss given a sudden growth on the number of used cells to
   the neighbor. The OVERPROVISION value is implementation-specific. A
   value of OVERPROVISION equal to zero leads to queue growth and
   possible packet loss. In this case, there are no overprovisioned
   cells where a sudden growth on the number of cells can absorbed and
   detected.

```
+------------------+
|   Triggering     |
|   Event          |<-----+
|                  |      |
+------------------+      |
         |                |
         V                |
+------------------+      |
| Collect number of|      |
| used cells       |      |
+------------------+      |
         |                |
         V                |
+------------------+      |
|   used cells     |      |
|       +          |      |
|   OVERPROVISION   |      |
|       =          |      |
|   REQUIREDCELLS   |      |
+------------------+      |
         |                |
         V                |
+------------------+      |
|   REQUIREDCELLS   |      |
|       |          |      |
|       V          |------+
|   Allocation     |
|   Policy         |
+------------------+
```
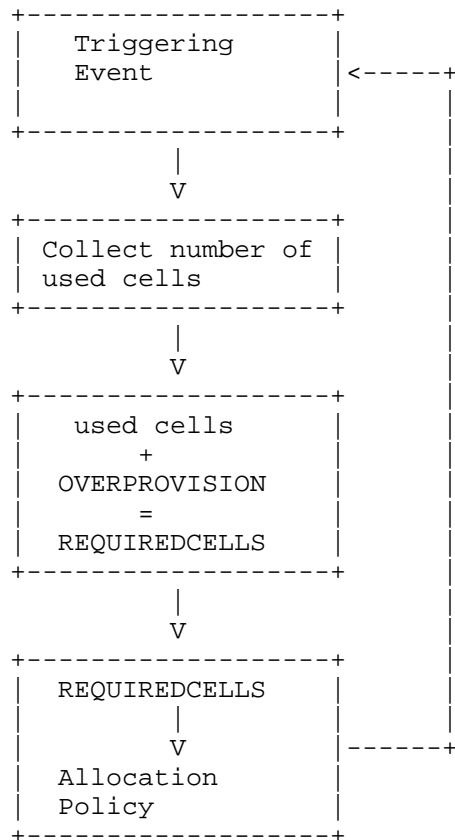
Figure 1: The SFX Estimation Algorithm

5.3. SFX Allocation Policy

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

   SFX 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 Cell Estimation
      Algorithm from the current node to that neighbor.
   SFXTHRESH: Threshold parameter introducing cell over-provisioning in
      the allocation policy. It is a non-negative value expressed as a
      number of cells. The definition of this value is implementation-

specific. A setting of SFXTHRESH>0 causes the node to allocate at
least SFXTHRESH cells to each of its' neighbors.

The SFX allocation policy compares REQUIREDCELLS with SCHEDULEDCELLS
and decides to add/delete cells taking into account SFXTHRESH. This
is illustrated in Figure 2. The number of cells to be added/deleted
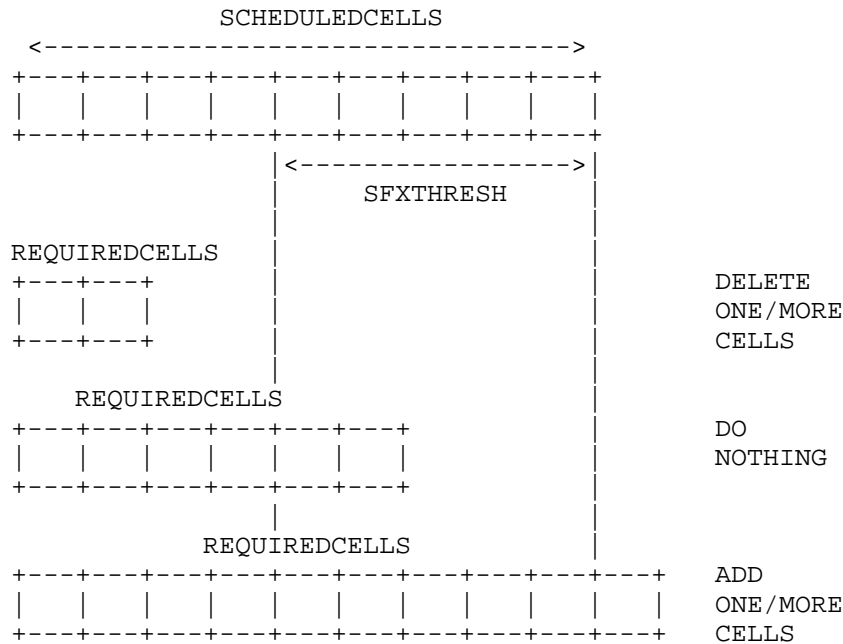is out of the scope of this document and it is implementation-
dependent.

```
                     SCHEDULEDCELLS
        <------------------------------->
       +---+---+---+---+---+---+---+---+---+
       |   |   |   |   |   |   |   |   |   |
       +---+---+---+---+---+---+---+---+---+
                     |<---------------->|
                     |   SFXTHRESH      |
                     |                  |
   REQUIREDCELLS     |                  |
   +---+---+         |                  |        DELETE
   |   |   |         |                  |        ONE/MORE
   +---+---+         |                  |        CELLS
                     |                  |
       REQUIREDCELLS |                  |
   +---+---+---+---+---+---+            |        DO
   |   |   |   |   |   |   |            |        NOTHING
   +---+---+---+---+---+---+            |
                     |                  |
         REQUIREDCELLS                  |
   +---+---+---+---+---+---+---+---+---+---+    ADD
   |   |   |   |   |   |   |   |   |   |   |    ONE/MORE
   +---+---+---+---+---+---+---+---+---+---+    CELLS
```

                 Figure 2: The SFX Allocation Policy

   1. If REQUIREDCELLS<(SCHEDULEDCELLS-SFXTHRESH), delete one or more
       cells.
   2. If (SCHEDULEDCELLS-SFXTHRESH)<=REQUIREDCELLS<=SCHEDULEDCELLS, do
       nothing.
   3. If SCHEDULEDCELLS<REQUIREDCELLS, add one or more cells.

When SFXTHRESH equals 0, any discrepancy between REQUIREDCELLS and
SCHEDULEDCELLS triggers an action to add/delete cells. Positive
values of SFXTHRESH reduce the number of 6P Transactions. The number
of cells to add or delete is implementation-specific.

6. Rules for CellList

   There are two methods to define the CellList. The Whitelist method
   fills the CellList with the number of proposed cells to the neighbor.
   The Blacklist method fills the CellList with the cells which cannot
   be used by the neighbor. The rule to select the method is
   implementation-specific. When issuing a 6top ADD Request, SFX
   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 is not occupied and choose channelOffset randomly for
         each cell.
         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 from the unallocated cells on the schedule, verifying
         that the slot offset is not occupied from the ones on the
         CellList.

   SFX does not include any transaction retry process. If the
   transaction is not successful, SFX will be retriggered on the next
   slotframe if the number of used cells changes.

7. 6P Timeout Value

   The timeout value is implementation-specific. The timeout value MAY
   be different for each transaction and each neighbor. The timeout
   range is from 0 to 128. The timeout MUST be added as an 7-bit on the
   Metadata header to the neighbor. There is no measurement unit
   associated to the timeout value. If the timeout expires, the node
   issues a RESET return code will be issued to the neighbor. SFX has
   no retry policy. Timeout examples are depicted on Figure 3 and
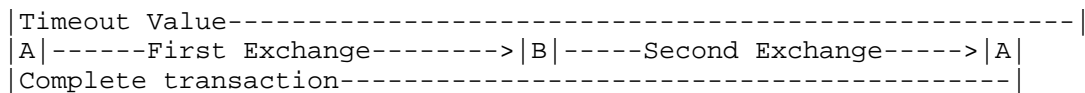   Figure 4.

   |Timeout Value---|
   |A|------First Exchange-------->|B|-----Second Exchange----->|A|
   |Complete transaction---|

      Figure 3: Example Transaction where the timeout does not expire

```
|Timeout Value-----------------------------------------------|
|A|------First Exchange-------->|B|-----Second Exchange----->|A|
|Non-Complete transaction------------------------------------|
```
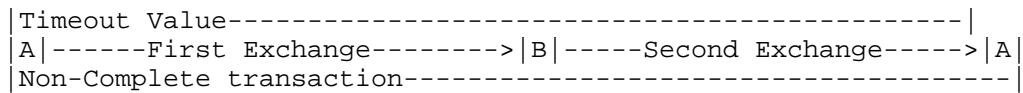
        Figure 4: Example Transaction where the timeout expires

8. 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 [TIMEOUT] represents the Timeout value
      BIT 15 [WBLIST] is used to indicate that the CellList provided is
      a Whitelist (value=0) or a Blacklist (value=1).

9. 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 neighbor nodes to enable a new
   allocation process and at least a SFXTHRESH number of cells MUST be
   allocated to each of the neighbors.

10. Cell Type

   SFX uses the TX (Transmission) cell type only, thus defining
   celloptions as TX=0, RX=1 and S=0 according to section 4.2.6 of
   [I-D.ietf-6tisch-6top-protocol].

11. SFX Statistics

   Packet Delivery Rate (PDR) is calculated per cell, as the percentage
   of acknowledged packets, for the last 10 packet transmission
   attempts. There is no retransmission policy on SFX.

12. Relocating Cells

   Allocated cells may experience packet loss from different sources,
   such as noise, interference or cell collision (after the same cell is
   allocated by other nodes in range on the network).

   SFX uses Packet Delivery Rate (PDR) statistics to monitor the
   currently allocated cells for cell relocation (by changing their
   slotOffset and/or channelOffset). When the PDR of one or more
   softcells is below PDR_THRESHOLD, SFX relocates each of the cell(s)
   to a number of available cells selected randomly. PDR_THRESHOLD is
   out of the scope of this document and it is implementation-dependent.

13. Forced Cell Deletion Policy

   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
   neighbor list. The action to follow this condition is out of scope
   of this document and it is implementation-dependent.

14. 6P Error Handling

   A node implementing SFX 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 ADD 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
      ADD Request, the neighbor has received the request, but less than
      NumCells of the cells in the CellList were allocated. 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_EOL: If an LIST command is issued and the RC_EOL is received, the
      node MUST understand what is specified on Section 3.3.5 of
      [I-D.ietf-6tisch-6top-protocol].
   RC_ERR_VER: The node MUST NOT retry immediately. The node MAY add
      the neighbor node to a blacklist. The node MAY retry to contact
      this neighbor later.
   RC_ERR_SFID: The node MUST NOT retry immediately. The node MAY add
      the neighbor node to a blacklist. The node MAY retry to contact
      this neighbor later.
   RC_ERR_SEQNUM: The node MUST issue a CLEAR command to the neighbor.
   RC_ERR_BUSY: Wait for a timeout and restart the scheduling process.
   RC_ERR_CELLLIST: Wait for a timeout and restart the scheduling
      process.
   RC_ERR_LOCKED: Wait for a timeout and restart the scheduling
      process.
   RC_RESET: Abort 6P Transaction.
   RC_ERR: Abort 6P Transaction. The node MAY retry to contact this
      neighbor later.

15. Experimental requirements

   In order to evaluate the performance of this draft, we propose the
   following experimental work:

1. Define values for OVERPROVISION, SFXTHRESH and ranges to the number of cells to Add or Delete after the Allocation Policy is applied for typical use cases.
2. Analyze the scheduling stability (in terms of oscillation) and the hysteresis effect on scheduling using SFX. A tradeoff shall be found between the reactivity of the algorithm facing new scheduling requirements and the number of overprovisioned cells.
3. Define the PDR value below the Average which is most effective for blacklisting cells and a method to whitelist cells. Analyze the stability and long-term behavior of this algorithm.
4. Measure the distribution of cell scheduling delay (including the time taken by 6P) to estimate timeouts for different type of transactions.

16. Security Considerations

   SFX is defined as an algorithm designed to efficiently fulfill bandwidth requirements between neighbour nodes and does not define a new protocol SFX uses the Minimal IPv6 over the TSCH Mode of IEEE 802.15.4e (6TiSCH) Configuration standardized on [RFC8180] and the 6top Protocol (6P): [I-D.ietf-6tisch-6top-protocol]. SFX relies on the security framework described on [I-D.ietf-6tisch-minimal-security].

17. IANA Considerations

17.1. SFX Scheduling Function Identifiers

   This document provide a new element to the "6P Scheduling Function Identifiers" sub-registry, which is part of the "IPv6 over the TSCH mode of IEEE 802.15.4e (6TiSCH) parameters" registry, as defined by [I-D.ietf-6tisch-6top-protocol]. This Subtype is defined on figure Figure 5

```
+----------------------+-------------------------+-------------+
|   SFID               | Name                    | Reference   |
+----------------------+-------------------------+-------------+
| IANA_6TISCH_SFID_SFX | Experimental Scheduling | RFCXXXX     |
|                      | Function (SFX)          | (NOTE:this) |
+----------------------+-------------------------+-------------+
```

Figure 5: IETF IE Subtype '6P'

18. 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 SFX
and the 6top sublayer.

19. References

19.1. Normative References

   [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate
              Requirement Levels", BCP 14, RFC 2119,
              DOI 10.17487/RFC2119, March 1997,
              <https://www.rfc-editor.org/info/rfc2119>.

   [RFC8180] Vilajosana, X., Ed., Pister, K., and T. Watteyne, "Minimal
              IPv6 over the TSCH Mode of IEEE 802.15.4e (6TiSCH)
              Configuration", BCP 210, RFC 8180, DOI 10.17487/RFC8180,
              May 2017, <https://www.rfc-editor.org/info/rfc8180>.

19.2. Informative References

   [I-D.ietf-6tisch-6top-protocol]
              Wang, Q., Vilajosana, X., and T. Watteyne, "6top Protocol
              (6P)", draft-ietf-6tisch-6top-protocol-09 (work in
              progress), October 2017.

   [I-D.ietf-6tisch-minimal-security]
              Vucinic, M., Simon, J., Pister, K., and M. Richardson,
              "Minimal Security Framework for 6TiSCH", draft-ietf-
              6tisch-minimal-security-04 (work in progress), October
              2017.

   [I-D.ietf-6tisch-terminology]
              Palattella, M., Thubert, P., Watteyne, T., and Q. Wang,
              "Terms Used in IPv6 over the TSCH mode of IEEE 802.15.4e",
              draft-ietf-6tisch-terminology-10 (work in progress), March
              2018.

Authors' Addresses

Diego Dujovne (editor)
Universidad Diego Portales
Escuela de Informatica y Telecomunicaciones
Av. Ejercito 441
Santiago, Region Metropolitana
Chile

Phone: +56 (2) 676-8121
Email: diego.dujovne@mail.udp.cl

Luigi Alfredo Grieco
Politecnico di Bari
Department of Electrical and Information Engineering
Via Orabona 4
Bari 70125
Italy

Phone: 00390805963911
Email: a.grieco@poliba.it

Maria Rita Palattella
Luxembourg Institute of Science and Technology (LIST)
Department 'Environmental Research and Innovation' (ERIN)
41, rue du Brill
Belvaux L-4422
Grand-duchy of Luxembourg

Phone: +352 275 888-5055
Email: mariarita.palattella@list.lu

Nicola Accettura
LAAS-CNRS
7, avenue du Colonel Roche
Toulouse 31400
France

Phone: +33 5 61 33 69 76
Email: nicola.accettura@laas.fr