             Transmission of IPv6 Packets over DECT Ultra Low Energy
                   draft-mariager-6lo-v6over-dect-ule-03

Abstract

   DECT Ultra Low Energy is a low power air interface technology that is
   defined by the DECT Forum and specified by ETSI.

   The DECT air interface technology has been used world-wide in
   communication devices for more than 15 years, primarily carrying
   voice for cordless telephony but has also been deployed for data
   centric services.

   The DECT Ultra Low Energy is a recent addition to the DECT interface
   primarily intended for low-bandwidth, low-power applications such as
   sensor devices, smart meters, home automation etc. As the DECT Ultra
   Low Energy interface inherits many of the capabilities from DECT, it
   benefits from long range, interference free operation, world wide
   reserved frequency band, low silicon prices and maturity. There is
   an added value in the ability to communicate with IPv6 over DECT ULE
   such as for Internet of Things applications.

   This document describes how IPv6 is transported over DECT ULE using
   6LoWPAN techniques.

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

   DECT Ultra Low Energy (DECT ULE or just ULE) is an air interface
   technology building on the key fundamentals of traditional DECT /
   CAT-iq but with specific changes to significantly reduce the power
   consumption on the expense of data throughput. DECT ULE devices with
   requirements to power consumption will operate on special power
   optimized silicon, but can connect to a DECT Gateway supporting
   traditional DECT / CAT-iq for cordless telephony and data as well as
   the ULE extensions. DECT terminology operates with two major role
   definitions: The Portable Part (PP) is the power constrained device,
   while the Fixed Part (FP) is the Gateway or base station. This FP
   may be connected to the Internet. An example of a use case for DECT
   ULE is a home security sensor transmitting small amounts of data (few
   bytes) at periodic intervals through the FP, but is able to wake up
   upon an external event (burglar) and communicate with the FP.
   Another example incorporating both DECT ULE as well as traditional
   CAT-iq telephony is an elderly pendant (broche) which can transmit
   periodic status messages to a care provider using very little
   battery, but in the event of urgency, the elderly person can
   establish a voice connection through the pendant to an alarm service.
   It is expected that DECT ULE will be integrated into many residential
   gateways, as many of these already implements DECT CAT-iq for
   cordless telephony. DECT ULE can be added as a software option for
   the FP. It is desirable to consider IPv6 for DECT ULE devices due to
   the large address space and well-known infrastructure. This document
   describes how IPv6 is used on DECT ULE links to optimize power while
   maintaining the many benefits of IPv6 transmission. [RFC4944]
   specifies the transmission of IPv6 over IEEE 802.15.4. DECT ULE has
   in many ways similar characteristics of IEEE 802.15.4, but also
   differences. Many of the mechanisms defined in [RFC4944] can be
   applied to the transmission of IPv6 on DECT ULE links.

   This document specifies how to map IPv6 over DECT ULE inspired by
   [RFC4944].

1.1. Requirements Notation

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

1.2. Terms Used

   PP: DECT Portable Part, typically the sensor node

   FP: DECT Fixed Part, the gateway

LLME: Lower Layer Management Entity

NWK: Network

PVC: Permanent Virtual Circuit

FAR: Fragmentation and Reassembly

2. DECT Ultra Low Energy

DECT ULE is a low power air interface technology that is designed to support both circuit switched for service, such as voice communication, and for packet mode data services at modest data rate. This draft is only addressing the packet mode data service of DECT ULE.

2.1. The DECT ULE Protocol Stack

The DECT ULE protocol stack consists of the PHY layer operating at frequencies in the 1880 - 1920 MHz frequency band depending on the region and uses a symbol rate of 1.152 Mbps. Radio bearers are allocated by use of FDMA/TDMA/TDD technics.

In its generic network topology, DECT is defined as a cellular network technology. However, the most common configuration is a star network with a single FP defining the network with a number of PP attached. The MAC layer supports both traditional DECT as this is used for services like discovery, pairing, security features etc. All these features have been reused from DECT.

The DECT ULE device can switch to the ULE mode of operation, utilizing the new ULE MAC layer features. The DECT ULE Data Link Control (DLC) provides multiplexing as well as segmentation and re-assembly for larger packets from layers above. The DECT ULE layer also implements per-message authentication and encryption. The DLC layer ensures packet integrity and preserves packet order, but delivery is based on best effort.

The current DECT ULE MAC layer standard supports low bandwidth data broadcast. However the usage of this broadcast service has not yet been standardized for higher layers. This document is not considering usage of this DECT ULE MAC broadcast service in current version.

In general, communication sessions can be initiated from both FP and PP side. Depending of power down modes employed in the PP, latency may occur when initiating sessions from FP side. MAC layer communication can either take place using connection oriented packet

transfer with low overhead for short sessions or take place using
connection oriented bearers including media reservation. The MAC
layer autonomously selects the radio spectrum positions that are
available within the band and can rearrange these to avoid
interference. The MAC layer has built-in retransmission procedures
in order to improve transmission reliability.

The DECT ULE device will typically incorporate an Application
Programmers Interface (API) as well as common elements known as
Generic Access Profile (GAP) for enrolling into the network. The
DECT ULE stack establishes a permanent virtual circuit (PVC) for the
application layers and provides support for a range of different
application protocols. The used application protocol is negotiated
between the PP and FP when the PVC communication service is
established. This draft proposes to define 6LoWPAN as one of the
possible protocols to negotiate.

```
    +---------------------------------------------+
    |                Applications                 |
    +---------------------------------------------+
    | Generic Access     |     ULE Profile        |
    |      Profile       |                        |
    +---------------------------------------------+
    | DECT/Service API   | ULE Data API           |
    +-------------------+-------------------------+
    | LLME  | NWK (MM,CC)|                        |
    +-------------------+-------------------------+
    | DECT DLC           | DECT ULE DLC           |
    +-------------------+-------------------------+
    |                MAC Layer                    |
    +-------------------+-------------------------+
    |                Physical Layer               |
    +-------------------+-------------------------+
         (C-plane)                (U-plane)
```
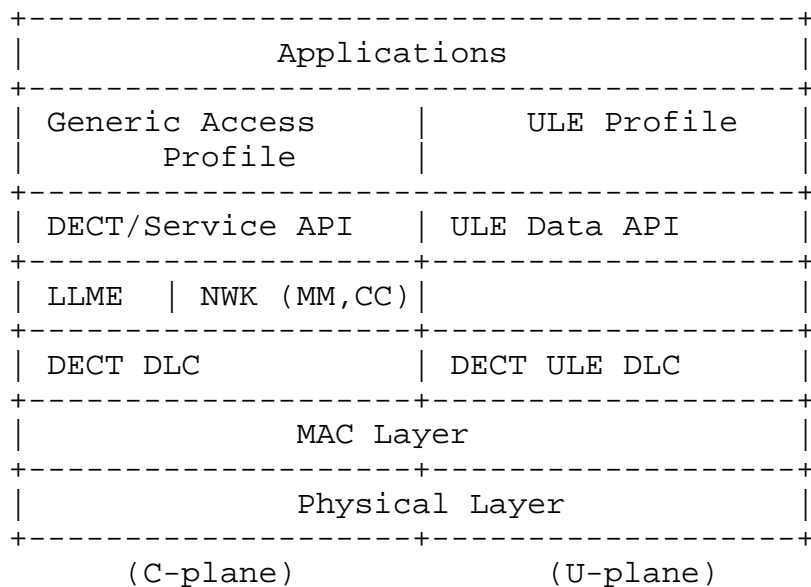
        Figure 1: DECT ULE Protocol Stack

The DECT ULE stack can be divided into control (C-plane) and user-
data (U-plane) parts shown to the left and to the right in figure 1,
respectively.

2.2. Link layer roles and topology

A FP is assumed to be less constrained than a PP. Hence, in the
primary scenario FP and PP will act as 6LoWPAN Border Router (6LBR)

and a 6LoWPAN Node (6LN), respectively. This document does only
address this primary scenario.

In DECT ULE, communication only takes place between a FP and a PP. A
FP is able to handle multiple simultaneous connections with a number
of PP. Hence, in a DECT ULE network using IPv6, a radio hop is
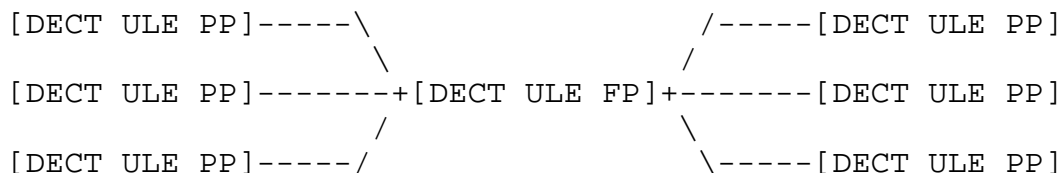equivalent to an IPv6 link and vice versa.

```
   [DECT ULE PP]-----\                          /-----[DECT ULE PP]
                      \                        /
   [DECT ULE PP]-------+[DECT ULE FP]+-------[DECT ULE PP]
                      /                        \
   [DECT ULE PP]-----/                          \-----[DECT ULE PP]
```

         Figure 2: DECT ULE star topology

DECT ULE repeaters are not considered in this proposal.

2.3. Addressing Model

Each DECT PP is assigned an <IPEI> (International Portable Equipment
Identity) during manufacturing. This identity has the size of 40
bits and is DECT globally unique for the PP and can be used to
constitute the MAC address. However, it can not be used to derive a
globally unique IID.

When bound to a FP, a PP is assigned a 20 bit TPUI (Temporary
Portable User Identity) which is unique within the FP. This TPUI is
used for addressing (layer 2) in messages between FP and PP.

Each DECT FP is assigned a <RFPI> (Radio Fixed Part Identity) during
manufacturing. This identity has the size of 40 bits and is globally
unique for a FP and can be used to constitute the MAC address.
However, it can not be used to derive a globally unique IID.

Alternatively each DECT PP and DECT FP can be assigned a unique
(IEEE) MAC-48 address additionally to the DECT identities to be used
by the 6LoWPAN. With such an approach, the FP and PP have to
implement a mapping between used MAC-48 addresses and DECT
identities.

2.4. MTU Considerations

   Generally the DECT ULE FP and PP may be generating data that fits
   into one MAC Layer packet (38 bytes) for periodically transferred
   information, depending on application. IP data packets may be much
   larger and hence MTU size should be the size of the IP data packet.
   The DECT ULE DLC procedures supports segmentation and reassembly of
   any MTU size below 65536 bytes, but most implementations do only
   support smaller values.

   It is expected that the LOWPAN_IPHC packet will fulfill all the
   requirements for header compression without spending unnecessary
   overhead for mesh addressing.

   It is important to realize that the support of larger packets will be
   on the expense of battery life, as a large packet will be fragmented
   into several or many MAC layer packets, each consuming power to
   transmit / receive.

2.5. Additional Considerations

   The DECT ULE standard allows PP to be registered (bind) to multiple
   FP and roaming between these FP. This draft does not consider the
   scenarios of PP roaming between multiple FP. The use of repeater
   functionality is also not considered in this draft.

3. Specification of IPv6 over DECT ULE

   DECT ULE technology sets strict requirements for low power
   consumption and thus limits the allowed protocol overhead. 6LoWPAN
   standards [RFC4944], [RFC6775], and [RFC6282] provide useful
   functionality for reducing overhead which can be applied to DECT ULE.
   This functionality comprises link-local IPv6 addresses and stateless
   IPv6 address autoconfiguration, Neighbor Discovery and header
   compression.

   The ULE 6LoWPAN adaptation layer can run directly on this U-plane DLC
   layer. Figure 3 illustrates IPv6 over DECT ULE stack.

   A significant difference between IEEE 802.15.4 and DECT ULE is that
   the former supports both star and mesh topology (and requires a
   routing protocol), whereas DECT ULE in it's primary configuration
   does not support the formation of multihop networks at the link
   layer. In consequence, the mesh header defined in [RFC4944] for mesh
   under routing MUST NOT be used in DECT ULE networks. In addition, a
   DECT ULE PP node MUST NOT play the role of a 6LoWPAN Router (6LR).

3.1. Protocol stack

   In order to enable transmission of IPv6 packets over DECT ULE, a
   Permanent Virtual Circuit (PVC) has to be opened between FP and PP.
   This MUST be done by setting up a service call from PP to FP. The PP
   SHALL specify the <<IWU-ATTRIBUTES>> in a service-change (other)
   message before sending a service-change (resume) message as defined
   in [TS102.939-1]. The <<IWU-ATTRIBTES>> SHALL define the ULE
   Application Protocol Identifier to 0x06 (reserved for 6LoWPAN and has
   to be standardized by ETSI) and the MTU size to 1280 octets or
   larger. The FP MUST send a service-change-accept (resume) containing
   a valid paging descriptor. The PP MUST be pageable.

```
              +-------------------+
              |   UDP/TCP/other   |
              +-------------------+
              |      IPv6         |
              +-------------------+
              |6LoWPAN adapted to |
              |    DECT ULE       |
              +-------------------+
              |  DECT ULE DLC     |
              +-------------------+
              |  DECT ULE MAC     |
              +-------------------+
              |  DECT ULE PHY     |
              +-------------------+
```
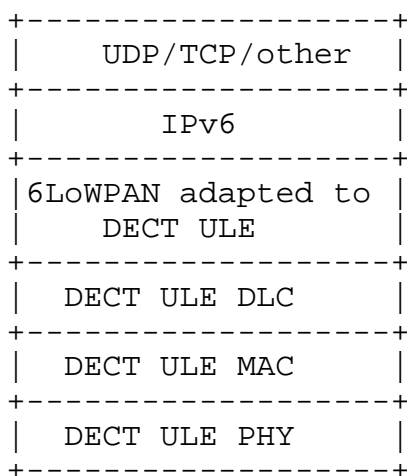
                Figure 3: IPv6 over DECT ULE Stack

3.2. Link model

   The general model is that IPv6 is layer 3 and DECT ULE MAC+DLC is
   layer 2. The DECT ULE implements FAR functionality and [RFC4944]
   MUST NOT be used. Since IPv6 requires MTU size of at least 1280
   octets, the DECT ULE connection (PVC) must be configured with
   configured with equivalent MTU size.

   This specification also assumes the IPv6 header compression format
   specified in [RFC6282]. It is also assumed that the IPv6 payload
   length can be inferred from the ULE DLC packet length and the IID
   value inferred from the link-layer address.

   Due to DECT ULE star topology, each branch of the star is considered
   to be an individual link and thus the PPs cannot directly hear one
   another and also cannot talk to one another with link-local

addresses. After the FP and PPs have connected at the DECT ULE
level, the link can be considered up and IPv6 address configuration
and transmission can begin. The FP ensures address collisions do not
occur.

3.2.1. Stateless address autoconfiguration

A DECT ULE 6LN performs stateless address autoconfiguration as per
[RFC4862]. A 64-bit Interface identifier (IID) for a DECT ULE
interface MAY be formed by utilizing a MAC-48 device address as
defined in [RFC2464] "IPv6 over Ethernet" specification.
Alternatively, the DECT device addresses IPEI, RFPI or TPUI, MAY be
used instead to derive the IID. In the case of randomly generated
IID or use of IID derived from DECT devices addresses, the "Universal
/Local" bit MUST be set to 0. Only if a global unique MAC-48 is used
the "Universal/Local" bit can be set to 1.

As defined in [RFC4291], the IPv6 link-local address for a DECT ULE
node is formed by appending the IID, to the prefix FE80::/64, as
shown in Figure 4.

```
       10 bits         54 bits                64 bits
      +----------+----------------+----------------------+
      |1111111010|     zeros      | Interface Identifier |
      +----------+----------------+----------------------+
```
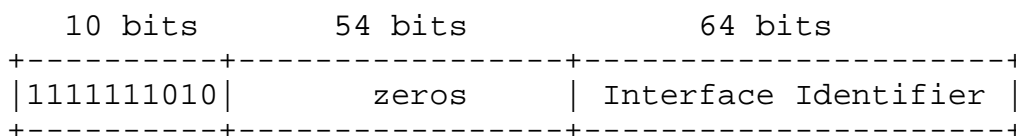
                 Figure 4: IPv6 link-local address in DECT ULE

The means for a 6LBR to obtain an IPv6 prefix for numbering the DECT
ULE network is out of scope of this document, but can be, for
example, accomplished via DHCPv6 Prefix Delegation [RFC3633] or by
using Unique Local IPv6 Unicast Addresses (ULA) [RFC4193]. Due to
the link model of the DECT ULE the 6LBR MUST set the "on-link" flag
(L) to zero in the Prefix Information Option [RFC4861]. This will
cause 6LNs to always send packets to the 6LBR, including the case
when the destination is another 6LN using the same prefix.

3.2.2. Neighbor discovery

'Neighbor Discovery Optimization for IPv6 over Low-Power Wireless
Personal Area Networks (6LoWPANs)' [RFC6775] describes the neighbor
discovery approach as adapted for use in several 6LoWPAN topologies,
including the mesh topology. As DECT ULE is considered not to
support mesh networks, hence only those aspects that apply to a star
topology are considered.

The following aspects of the Neighbor Discovery optimizations
[RFC6775] are applicable to DECT ULE 6LNs:

1. A DECT ULE 6LN MUST register its address with the 6LBR by sending
a Neighbor Solicitation (NS) message with the ARO option and process
the Neighbor Advertisement (NA) accordingly. The NS with the ARO
option SHOULD be sent irrespective of whether the IID is derived from
a unique MAC-48 bit device address, from the DECT ULE device
addresses or the IID is a random value that is generated as per the
privacy extensions for stateless address autoconfiguration [RFC4941].
Although [RFC4941] permits the use of deprecated addresses for old
connections, in this specification we mandate that one interface MUST
NOT use more than one IID at any one time.

2. For sending Router Solicitations and processing Router
Advertisements the DECT ULE 6LNs MUST, respectively, follow Sections
5.3 and 5.4 of the [RFC6775].

3.2.3. Unicast and Multicast address mapping

The DECT MAC layer broadcast service is considered inadequate for IP
multicast.

Hence traffic is always unicast between two DECT ULE nodes. Even in
the case where a FP is attached to multiple PPs, the FP cannot do a
multicast to all the connected PPs. If the FP needs to send a
multicast packet to all its PPs, it has to replicate the packet and
unicast it on each link. However, this may not be energy-efficient
and particular care must be taken if the FP is battery-powered. In
the opposite direction, a PP can only transmit data to a single
destination (i.e. the FP). Hence, when a PP needs to transmit an
IPv6 multicast packet, the PP will unicast the corresponding DECT ULE
packet to the FP. As described in the linkmodel section, the FP will
not forward link-local multicast messages to other PPs connected to
the FP.

3.2.4. Header Compression

Header compression as defined in [RFC6282], which specifies the
compression format for IPv6 datagrams on top of IEEE 802.15.4, is
REQUIRED in this document as the basis for IPv6 header compression on
top of DECT ULE. All headers MUST be compressed according to
[RFC6282] encoding formats. The DECT ULE's star topology structure
can be exploited in order to provide a mechanism for IID compression.
The following text describes the principles of IPv6 address
compression on top of DECT ULE.

In a link-local communication, both the IPv6 source and destination
addresses MUST be elided [RFC6282], since the node knows that the
packet is destined for it even if the packet does not have
destination IPv6 address. A node SHALL learn the IID of the other
endpoint of each DECT ULE connection it participates in. By
exploiting this information, a node that receives a PDU containing an
IPv6 packet can infer the corresponding IPv6 source address. A node
MUST maintain a Neighbor Cache, in which the entries include both the
IID of the neighbor and the Device Address that identifies the
neighbor. For the type of communication considered in this
paragraph, the following settings MUST be used in the IPv6 compressed
header: CID=0, SAC=0, SAM=11, DAC=0, DAM=11.

When a 6LN transmits an IPv6 packet to a remote destination using
global Unicast IPv6 addresses, if a context is defined for the prefix
of the 6LNs global IPv6 address, the 6LN MUST indicate this context
in the corresponding source fields of the compressed IPv6 header as
per Section 3.1 of [RFC6282], and MUST elide the IPv6 source address.
For this, the 6LN MUST use the following settings in the IPv6
compressed header: CID=1, SAC=1, SAM=11. In this case, the 6LBR can
infer the elided IPv6 source address since 1) the 6LBR has previously
assigned the prefix to the 6LNs; and 2) the 6LBR maintains a Neighbor
Cache that relates the Device Address and the IID of the
corresponding PP. If a context is defined for the IPv6 destination
address, the 6LN MUST also indicate this context in the corresponding
destination fields of the compressed IPv6 header, and MUST elide the
prefix of the destination IPv6 address. For this, the 6LN MUST set
the DAM field of the compressed IPv6 header as DAM=01 (if the context
covers a 64-bit prefix) or as DAM=11 (if the context covers a full,
128-bit address). CID and DAC MUST be set to CID=1 and DAC=1. Note
that when a context is defined for the IPv6 destination address, the
6LBR can infer the elided destination prefix by using the context.

When a 6LBR receives an IPv6 packet sent by a remote node outside the
DECT ULE network, and the destination of the packet is a 6LN, if a
context is defined for the prefix of the 6LN's global IPv6 address,
the 6LBR MUST indicate this context in the corresponding destination
fields of the compressed IPv6 header, and MUST elide the IPv6
destination address of the packet before forwarding it to the 6LN.
For this, the 6LBR MUST set the DAM field of the IPv6 compressed
header as DAM=11. CID and DAC MUST be set to CID=1 and DAC=1. If a
context is defined for the prefix of the IPv6 source address, the
6LBR MUST indicate this context in the source fields of the
compressed IPv6 header, and MUST elide that prefix as well. For
this, the 6LBR MUST set the SAM field of the IPv6 compressed header
as SAM=01 (if the context covers a 64-bit prefix) or SAM=11 (if the
context covers a full, 128-bit address). CID and SAC MUST be set to
CID=1 and SAC=1.

3.3. Internet connectivity scenarios

   In a typical scenario, the DECT ULE network is connected to the
   Internet as shown in the Figure 5.

   A degenerate scenario can be imagined where a PP is acting as 6LBR
   and providing Internet connectivity for the FP. How the FP could
   then further provide Internet connectivity to other PP, possibly
   connected to the FP, is out of the scope of this document.


```
                        6LN
                          \           _____
                           \         /            \
                   6LN ---- 6LBR --- |   Internet     |
                           /         _____/
                          /
                        6LN

                  <-- DECT ULE -->
```
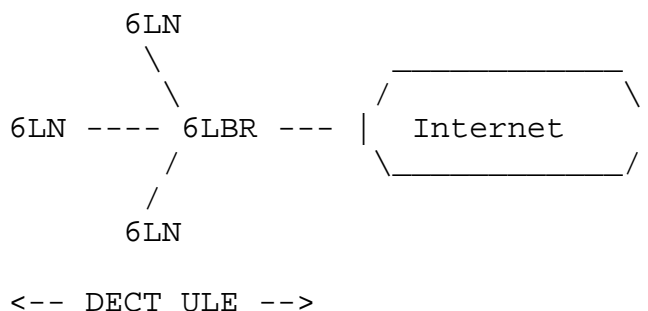
              Figure 5: DECT ULE network connected to the Internet

   In some scenarios, the DECT ULE network may transiently or
   permanently be an isolated network as shown in the Figure 6.


```
                        6LN        6LN
                          \        /
                           \      /
                   6LN --- 6LBR --- 6LN
                           /     \
                          /       \
                        6LN        6LN

                  <------ DECT ULE ----->
```
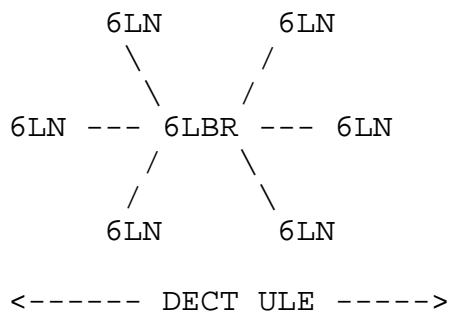
                    Figure 6: Isolated DECT ULE network

   In the isolated network scenario, communications between 6LN and 6LBR
   can use IPv6 link-local methodology, but for communications between
   different PP, the FP has to act as 6LBR, number the network with ULA
   prefix [RFC4193], and route packets between PP.

4. IANA Considerations

    There are no IANA considerations related to this document.

5. Security Considerations

    The secure transmission of speech over DECT will be based on the
    DSAA2 and DSC2 work being developed by the DF Security group / ETSI
    TC DECT and the ETSI SAGE Security expert group.

    DECT ULE communications are secured at the link-layer (DLC) by
    encryption and per-message authentication through CCM mode (Counter
    with CBC-MAC) similar to [RFC3610]. The underlying algorithm for
    providing encryption and authentication is AES128.

    The DECT ULE pairing procedure generates a master authentication key
    (UAK) and during location registration procedure or when the
    permanent virtual circuit are established, the session security keys
    are generated. Session security keys may be renewed regularly. The
    generated security keys (UAK and session security keys) are
    individual for each FP-PP binding, hence all PP in a system have
    different security keys. DECT ULE PPs do not use any shared
    encryption key.

6. ETSI Considerations

    ETSI is standardizing a list of known application layer protocols
    that can use the DECT ULE permanent virtual circuit packet data
    service. Each protocol is identified by a unique known identifier,
    which is exchanged in the service-change procedure as defined in
    [TS102.939-1]. The IPv6/6LoWPAN as described in this document is
    considered as an application layer protocol on top of DECT ULE. In
    order to provide interoperability between 6LoWPAN / DECT ULE devices
    a common protocol identifier for 6LoWPAN has to be standardized by
    ETSI.

    It is proposed to use ETSI DECT ULE Application Protocol Identifier
    equal 0x06 for 6LoWPAN.

7. Acknowledgements

8. Normative References

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