6Lo Working Group
Internet-Draft
Intended status: Standards Track
Expires: April 19, 2016
October 17, 2015

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Use cases for IPv6 over Networks of Resource-constrained Nodes
draft-hong-6lo-use-cases-00

Abstract

This document describes the characteristics of link layer technologies that are used at constrained node networks and typical use cases of IPv6 over networks of resource-constrained nodes. In addition to IEEE 802.15.4, various link layer technologies such as BLE, Z-wave, DECT-ULE, MS/TP, NFC, and IEEE 802.15.4e are widely used at constrained node networks for typical services. Based on these link layer technologies, IPv6 over networks of resource-constrained nodes has various and practical use cases. To efficiently implement typical services, the applicability and consideration of several design spaces are described.

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1. Introduction

Running IPv6 on constrained node networks has different features due to the characteristics of constrained node networks such as small packet size, short link-layer address, low bandwidth, network topology, low power, low cast, and large number of devices [RFC4919]. For example, because some IEEE 802.15.4 link layers have an MTU of 127 octets and IPv6 requires 1280 bytes, an appropriate fragmentation and reassembly adaptation layer must be provided at the layer of below IPv6. Also, due to the limited size of IEEE 802.15.4 frame and the length shortage of data delivery, it makes the need for header compression. IETF 6lowpan (IPv6 over low power and WPAN) working group published [RFC4944], an adaptation layer for sending IPv6 packets over low power WPAN, [RFC6282], compression format for IPv6 datagrams over IEEE 802.15.4-based networks, and [RFC6775], Neighbor Discovery Optimization for 6lowpan.

As IoT (Internet of Things) services becomes more popular, various link layer technologies such as BLE, Z-wave, DECT-ULE, MS/TP, NFC, and IEEE 802.15.4e are actively used. And the need of transmission of IPv6 packets over these link layer technologies is required. A number of IPv6-over-foo documents have been developed in the IETF 6lo (IPv6 over Networks of Resource-constrained Nodes) and 6tisch (IPv6 over the TSCH mode of IEEE 802.15.4e) working group.

In the 6lowpan working group, the [RFC6568], "Design and Application Spaces for 6LoWPANs" was published and it describes potential application scenarios and use cases for low-power wireless personal area networks. In this document, various design spaces such as deployment, network size, power source, connectivity, multi-hop communication, traffic pattern, security level, mobility, and QoS were analyzed. And it described a fundamental set of 6lowpan application scenarios and use cases; Industrial monitoring-Hospital storage rooms, Structural monitoring-Bridge safety monitoring, Connected home-Home Automation, Healthcare-Healthcare at home by tele-assistance, Vehicle telematics-telematics, and Agricultural monitoring-Automated vineyard.

Even though the [RFC6568] describes some potential application scenarios and use cases and it lists the design space in the context of 6lowpan, it needs a different use cases and design space in the context of the 6lo working group to provide practical information of 6lo technologies. To do this, the use case of 6lo is required to consider the followings;

- o 6lo use cases SHOULD be uniquely different to the 6lowpan use cases.
- o 6lo use cases SHOULD cover various IoT related wire/wireless link layer technology including the IEEE 802.15.4.
- o 6lo use cases MAY describe characteristics of each link layer technologies and typical use case of each link layer technology and then 6lo use cases’s applicability.

2. Conventions and Terminology

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].

3. 6lo Link layer technologies

3.1. ITU-T G.9959

The ITU-T G.9959 recommendation G. [G.9959] targets low-power Personal Area Networks (PANs). G.9959 defines how a unique 32-bit HomeID network identifier is assigned by a network controller and how an 8-bit NodeID host identifier is allocated to each node. NodeIDs are unique within the network identified by the HomeID. The G.9959 HomeID represents an IPv6 subnet that is identified by one or more IPv6 prefixes [RFC7428].

3.2. Bluetooth Low Energy

Bluetooth LE was introduced in Bluetooth 4.0, enhanced in Bluetooth 4.1, and developed even further in successive versions. Bluetooth SIG has also published Internet Protocol Support Profile (IPSP), which includes Internet Protocol Support Service (IPSS). The IPSP enables discovery of IP-enabled devices and establishment of link-layer connection for transporting IPv6 packets. IPv6 over Bluetooth LE is dependent on both Bluetooth 4.1 and IPSP 1.0 or newer.

Devices such as mobile phones, notebooks, tablets and other handheld computing devices which will include Bluetooth 4.1 chipsets will also have the low-energy functionality of Bluetooth. Bluetooth LE will also be included in many different types of accessories that collaborate with mobile devices such as phones, tablets and notebook computers. An example of a use case for a Bluetooth LE accessory is a heart rate monitor that sends data via the mobile phone to a server on the Internet [I-D.ietf-6lo-btle].

3.3. DECT-ULE

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.

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 [I-D.ietf-6lo-dect-ule].

3.4. Master-Slave/Token-Passing

Master-Slave/Token-Passing (MS/TP) is a contention-free access method for the RS-485 physical layer, which is used extensively in building automation networks. This specification defines the frame format for transmission of IPv6 [RFC2460] packets and the method of forming link-local and statelessly autoconfigured IPv6 addresses on MS/TP networks. The general approach is to adapt elements of the 6LoWPAN [RFC4944] specification to constrained wired networks.

An MS/TP device is typically based on a low-cost microcontroller with limited processing power and memory. Together with low data rates and a small address space, these constraints are similar to those faced in 6LoWPAN networks and suggest some elements of that solution might be leveraged. MS/TP differs significantly from 6LoWPAN in at least three respects: a) MS/TP devices typically have a continuous source of power, b) all MS/TP devices on a segment can communicate directly so there are no hidden node or mesh routing issues, and c) recent changes to MS/TP provide support for large payloads, eliminating the need for link-layer fragmentation and reassembly.

MS/TP is designed to enable multidrop networks over shielded twisted pair wiring. It can support a data rate of 115,200 baud on segments up to 1000 meters in length, or segments up to 1200 meters in length at lower baud rates. An MS/TP link requires only a UART, an RS-485 transceiver with a driver that can be disabled, and a 5ms resolution timer. These features make MS/TP a cost-effective field bus for the most numerous and least expensive devices in a building automation network [I-D.ietf-6lo-6lobac].

3.5. NFC

NFC technology enables simple and safe two-way interactions between electronic devices, allowing consumers to perform contactless transactions, access digital content, and connect electronic devices with a single touch. NFC complements many popular consumer level wireless technologies, by utilizing the key elements in existing standards for contactless card technology (ISO/IEC 14443 A&B and JIS-X 6319-4). NFC can be compatible with existing contactless card infrastructure and it enables a consumer to utilize one device across different systems.

Extending the capability of contactless card technology, NFC also enables devices to share information at a distance that is less than 10 cm with a maximum communication speed of 424 kbps. Users can share business cards, make transactions, access information from a smart poster or provide credentials for access control systems with a simple touch.

NFC's bidirectional communication ability is ideal for establishing connections with other technologies by the simplicity of touch. In addition to the easy connection and quick transactions, simple data sharing is also available [I-D.ietf-6lo-nfc].

3.6. IEEE 802.15.4e TSCH

[TBD]

4. Design Space

The [RFC6568] lists the dimensions used to describe the design space of wireless sensor networks in the context of the 6LoWPAN working group. The design space is already limited by the unique characteristics of a LoWPAN (e.g., low power, short range, low bit rate). In the RFC 6558, the following design space is described; Deployment, Network size, Power source, Connectivity, Multi-hop communication, Traffic pattern, Mobility, Quality of Service (QoS).

The design space of 6lo is a little different to those of the RFC 6558 due to the different characteristics of 6lo link layer technologies. The following design space can be considered.

- o Network access/Bootstrapping: 6lo nodes can be connected randomly, or in an organized manner. The bootstrapping has different characteristics of each link layer technologies.

- o Topology: Topology of 6lo networks may inherently follow the characteristics of each link layer technologies. A star topology can be configured or point-to-point or mesh topology can be configured.

- o L2-Mesh or L3-Mesh: L2-mesh and L3-mesh may inherently follow the characteristics of each link layer technologies. Some link layer technologies may support L2-mesh and some may not support.

- o Multi-link subnet, single subnet: The selection of multi-link subnet and single subnet depends on connectivity and the number of 6lo nodes.

- o Data rate: Originally, the link layer technologies of 6lo has low rate of data transmission. But, by adjusting the MTU, it can deliver higher data rate.

- o Buffering requirements: Some 6lo use case may require more data rate than the link layer technology support. In this case, a buffering mechanism to manage the date is required.

- o Security Requirements: Some 6lo use case can transfer some important and personal data between 6lo nodes. In this case, high-level security support is required.

- o Mobility across 6lo networks and subnets: The movement of 6lo nodes is dependent on the 6lo use case. If the 6lo nodes can move or moved around, it requires the mobility management mechanism.

- o Time synchronization requirements: The requirement of time synchronization is dependent on the 6lo use case. For some 6lo use case related to health service, the measured data must be recorded with exact time and must be transferred with time synchronization.

- o Reliability and QoS: Some 6lo use case requires high reliability, for example real-time service or health-related services.

- o Data models: 6lo use case may various data models. Some 6lo use case may require short data length and randomly. Some 6lo use case may require continuous data and periodic data transmission.

- o Security Bootstrapping: Without the external operations, 6lo nodes must have the security bootstrapping mechanism.

5. 6lo Use Cases

5.1. Use case of NFC: Alternative Secure Transfer

According to applications, various secured data can be handled and transferred. Depending on security level of the data, methods for transfer can be alternatively selected. The personal data having serious issues should be transferred securely, but data transfer by using Wi-Fi and Bluetooth connections cannot always be secure because of their a little long radio frequency range. Hackers can overhear the personal data transfer behind hidden areas. Therefore, methods need to be alternatively selected to transfer secured data. Voice and video data, which are not respectively secure and requires long transmission range, can be transferred by 3G/4G technologies, such as WCDMA, GSM, and LTE. Big size data, which are not secure and requires high speed and broad bandwidth, can be transferred by Wi-Fi and wired network technologies. However, the person data, which are serious issues so requires secure transfer in wireless area, can be securely transferred by NFC technology. It has very short frequency range ? nearly single touch communication.

Example: Secure Transfer by Using NFC in Healthcare Services with Tele-Assistance

A senior citizen who lives alone wears one to several wearable 6lo devices to measure heartbeat, pulse rate, etc. The 6lo devices are densely installed at home for movement detection. An LoWPAN Border Router (LBR) at home will send the sensed information to a connected healthcare center. Portable base stations with LCDs may be used to check the data at home, as well. Data is gathered in both periodic and event-driven fashion. In this application, event-driven data can be very time-critical. In addition, privacy also becomes a serious issue in this case, as the sensed data is very personal.

While the senior citizen is provided audio and video healthcare services by a tele-assistance based on LTE connections, the senior citizen can alternatively use NFC connections to transfer the personal sensed data to the tele-assistance. At this moment, hidden hackers can overhear the data based on the LTE connection, but they cannot gather the personal data over the NFC connection.

```
+-------------+                              +-------------+
|voice & video|....... LTE connection ......>|voice & video|
|     data    |<...... LTE connection .......|    data     |
+-------------+                              +-------------+
| sensed data |....... NFC connection ......>|             |
|             |<...... NFC connection .......|   personal  |
|             |                              | result data |
+-------------+                              +-------------+
   (patient)                                (tele-assistance)
```

Figure 1: Alternative Secure Transfer in Healthcare Services

Dominant parameters in secure transfer by using NFC in healthcare services:

o Network access/Bootstrapping: Pre-planned. MP2P/P2MP (data collection), P2P (local diagnostic).

- o Topology: Small, NFC-enabled device connected to the Internet.

- o L2-mesh or L3-mesh: NFC does not support L2-mesh, L3-mesh can be configured.

- o Multi-link subnet, single subnet: a Single-hop for gateway; patient's body network is mesh topology.

- o Data rate: Small data rate.

- o Buffering requirements: Low requirement.

- o Security requirements: Data privacy and security must be provided. Encryption is required.

- o Mobility: Moderate (patient's mobility).

- o Time Synchronization: Highly required.

- o Reliability and QoS: High level of reliability support (life-or-death implication), role-based.

- o Data models: Short data length and periodic (randomly).

- o Security Bootstrapping: Highly required.

- o Other Issues: Plug-and-play configuration is required for mainly non-technical end-users. Real-time data acquisition and analysis are important. Efficient data management is needed for various devices that have different duty cycles, and for role-based data control. Reliability and robustness of the network are also essential.

5.2. Use case of ITU-T G.9959

[TBD]

5.3. Use case of Bluetooth Low Energy

[TBD]

5.4. Use case of DECT-ULE

[TBD]

5.5. Use case of Master-Slave/Token-Passing

[TBD]

5.6. Use case of IEEE 802.15.4e TSCH

[TBD]

6. IANA Considerations

There are no IANA considerations related to this document.

7. Security Considerations

[TBD]

8. Acknowledgements

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