State and Future of generic 6LoWPAN branch

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Abstract

6LoWPAN stands for IPv6 over Low-Rate Wireless Area Network and was original specified for IEEE 802.15.4 wireless networks. The IEEE 802.15.4 wireless standard is such Low-Rate WPAN standard. The 6LoWPAN stack provides an adaptation layer to run IPv6 on top of a specific link-layer like 802.15.4.

Nowadays 6LoWPAN isn't only an acronym for running IPv6 on top of WPANs anymore. There are several upcoming RFCs to run 6LoWPAN on various link-layers like NFC, Powerline, DECT, etc. The most link-layer 6LoWPAN RFCs for each new link-layer adaptation refers to the first original RFCs which is the IEEE 802.15.4 6LoWPAN specification. The reason behind that is to keeping same mechanism with slightly link-layer specific changes. The generic 6LoWPAN branch offers these mechanism which are specified by more than one link-layer 6LoWPAN specifications.

Keywords

Linux; 6LoWPAN; IPv6; IEEE 802.15.4; BTLE; WPAN; IoT

Introduction

6LoWPAN stands for IPv6 over Low-Power Wireless Area Networks and is an adaptation layer to run IPv6 on top of different link layers. Such link layers are known as a LoWPAN. These link layers have different challenges to getting IPv6 running for their typical LoWPAN constraints. 6LoWPAN is a protocol for the Internet of Things and offers a IPv6 connection for devices which using a LoWPAN link layer.

The challenge inside the Linux kernel is to provide a 6LoWPAN adaptation layer for for the already existing IPv6-Stack implementation. My idea is to introduce a general framework "generic 6LoWPAN" which offers a 6LoWPAN adaptation layer for every possible link layer implementationl.

LoWPAN

A LoWPAN Standard has several properties, these are:

- Wireless connection.
- Low-Range about 3 - 5 meters.
- Low-Rate e.g. bandwidth of IEEE 802.15.4 2.4 Ghz transceivers is 250 kbit/s.
- Low-Power consuming for battery powered devices.

In case of the Linux kernel the interesting LoWPAN layers are: Bluetooth Low-Energy, IEEE 802.15.4 and Near Field Communication. For these link layers exists a implementation inside the Linux kernel.

6LoWPAN

The IETF specifies for 6LoWPAN different headers which can be identified by a dispatch value. The main focus for 6LoWPAN headers are to reduce the payload of the IPv6-Packet. One of the 6LoWPAN headers describes an IP Header Compression (IPHC) format [1]. Such header compress tries to compress the IPv6- and possible next-headers to reduce the payload for the link layer. Another 6LoWPAN header describe a fragmentation mechanism to provide the minimum IPv6-MTU in cases when the LoWPAN link-layer doesn't support such MTU. As example the IEEE 802.15.4 LoWPAN standard defines a MTU of 127 bytes for one frame. To provide the minimum MTU of IPv6 which is 1280 bytes a fragmentation handling is needed [2].

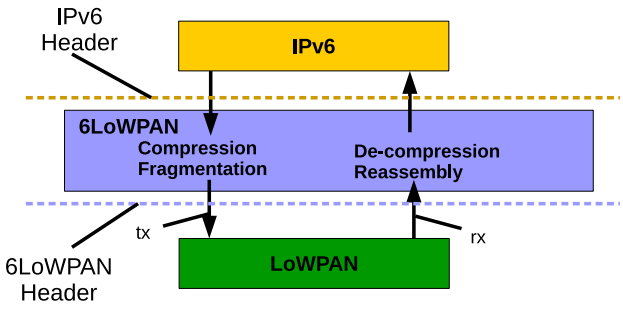

Figure 1: The 6LoWPAN adaptation layer.

Figure 1 shows how the 6LoWPAN adaptation layer in interaction with the LoWPAN and IPv6-Layer. The 6LoWPAN headers are originally defined for IEEE 802.15.4 but newly introduced 6LoWPAN adaptations like for Bluetooth Low-Energy uses the same mechanism. For example the IPHC format for the IPv6-Header compression will also be used by the Bluetooth Low-Energy 6LoWPAN specification. Outing RFC 7668: *"... the IPv6 header compression format specified in RFC 6282 MUST be used"*. RFC 6282 describes the

IPHC format in case of IEEE 802.15.4 as Link-Layer. The 6LoWPAN generic branch tries to share one implementation for both 6LoWPAN link layer implementations and abstract a general framework which can be used by several link layer implementation by the Linux kernel.

Framework

There are currently two different branches for the Linux 6LoWPAN subsystem. First the 6LoWPAN generic branch: "net/6lowpan/" and a 6LoWPAN specific link layer implementation branch: "net/ieee802154/6lowpan/" or "net/bluetooth/6lowpan.c". Inside the generic 6LoWPAN directory exists the shared implementation for handling 6LoWPAN headers, e.g. the compression and de-compression for the IPHC format.

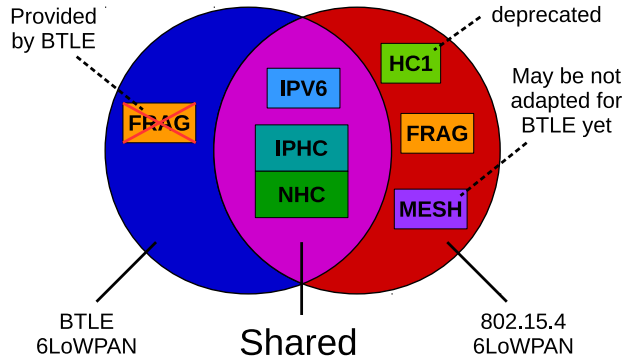

Figure 2: Venn-Diagramm about shared 6LoWPAN headers.

Figure 2 shows the shared header formats for IEEE 802.15.4 and Bluetooth Low-Energy LoWPANs. The goal of the generic 6LoWPAN branch is to provide a framework which offers a 6LoWPAN capable connection for a LoWPAN implementation.

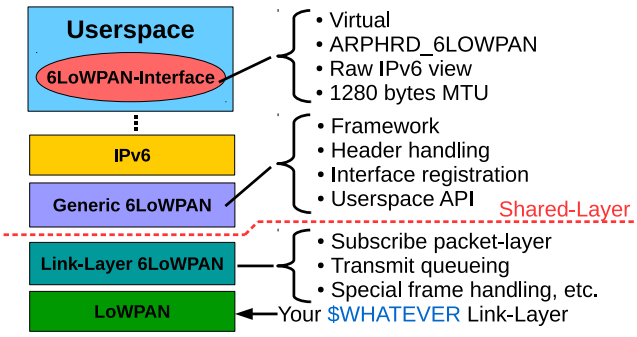

Figure 3: Framework-Architecture.

Figure 3 shows the architecture for handling 6LoWPAN inside the Linux kernel. At userspace layer a 6LoWPAN interface will be available and has a raw IPv6 view. Finally the userspace should not get notice about the used link-layer inside the kernel space. All 6LoWPAN related userspace software should be not depend on the link layer.

Future Work

There are mainly three topics which need to be work on Linux to provide 6LoWPAN: generic 6LoWPAN, neighbor discovery and RPL.

Generic 6LoWPAN

The framework which is described in this paper isn't done yet. Historical issues are the reason that the generic 6LoWPAN branch contains IPHC compress and de-compress functionality only. The proposed framework should contain all 6LoWPAN header handling and should be loaded when it's needed only. This means all each 6LoWPAN header implementations are per module and will be registered inside the generic 6LoWPAN branch. Also the receive and transmit handling to create/parse 6LoWPAN headers should be moved to generic 6LoWPAN branch.

Neighbor Discovery

Another topic is RFC 6775 [4] which describes neighbor discovery optimizations for 6LoWPAN. It introduce new message types and message options for neighbor solicitations and neighbor advertisements. There exists three different roles for nodes these are: 6LBR (6LoWPAN Border-Router), 6LR (6LoWPAN Router) and 6LN (6LoWPAN Node). The objectives are to reduce e.g. IPv6 multicast packets which isn't available at wireless communications which ends in a reducing of power consuming. RFC 6775 isn't implemented yet inside the Linux kernel and the challenge is to provide this implementation apart from the IPv6 neighbor discovery.

RPL

RPL [5] (pronounced "ripple") is a routing protocol for low power and lossy networks (LLN). A 6LoWPAN network is a LLN. It's a router-over routing protocol and uses ICMPv6 message types. There exists an userspace implementation about RPL named "unstrung" [3]. High priority use-case for Linux machines would be to run a RPL border router. This requires the neighbor discovery optimizations from RFC 6775.

References

[1] Hui, J., and Thubert, P. 2011. Compression Format for IPv6 Datagrams over IEEE 802.15.4-Based Networks. RFC 6282 (Proposed Standard).

[2] Montenegro, G.; Kushalnagar, N.; Hui, J.; and Culler, D. 2007. Transmission of IPv6 Packets over IEEE 802.15.4 Networks. RFC 4944 (Proposed Standard). Updated by RFCs 6282, 6775.

[3] Richardson, M. unstrung. http://unstrung.sandelman.ca/. [Online; accessed 09-January-2016].

[4] Shelby, Z.; Chakrabarti, S.; Nordmark, E.; and Bormann, C. 2012. Neighbor Discovery Optimization for IPv6 over Low-Power Wireless Personal Area Networks (6LoWPANs). RFC 6775 (Proposed Standard).

[5] Winter, T.; Thubert, P.; Brandt, A.; Hui, J.; Kelsey, R.; Levis, P.; Pister, K.; Struik, R.; Vasseur, J.; and Alexander, R. 2012. RPL: IPv6 Routing Protocol for Low-Power and Lossy Networks. RFC 6550 (Proposed Standard).