Indian Journal of Science and Technology, *Vol 9(30), DOI: 10.17485/ijst/2016/v9i30/98730, August 2016*
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

IPv6 Low Power Wireless Personal Area Network (6LoWPAN) for Networking Internet of Things (IoT) – Analyzing its Suitability for IoT

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Abstract

Background/Objectives: Internet of Things (IoT) is going to govern the future world where all devices will be connected with each-other. The expectation with the Internet of Things is that the increase in number of devices going to be truly dramatic. **Method:** With the increase in the number of devices, the amount of traffic will grow together with data. IoT will have huge number of power sensitive smaller devices and they're going to put significant constraint on the total bandwidth of the system. This paper analyses how 6LoWPAN, a practical developed for resource constrained IP based systems suitable for Internet of Things with respect to Internet Protocol. **Findings/Applications:** Internet protocols used to be fine-tuned, modified, changed to be able to accommodate the era of Internet of Things. 6LoWPAN has different features like, support for 64 bit or 16-bit addressing, targeted at low power networks including Bluetooth low energy, header compression for IPv base as well as for UDP headers, network auto configuration and neighbor discovery, support for multicast, unicast, and broadcast, supporting the concept of fragmentation. This makes 6LoWPAN a best suited protocol for IoT.

Keywords: 6LoWPAN, Communication Protocol, Internet of Things, Internet Protocol, Smart Device Integration

1. Introduction

Internet of Things, an emerging technology that can attach all small devices with limited capability that operated by the user's control to the Internet. According to Gartner, "26 billion or more devices will be cross connected to create and innovate business opportunities"[1]. Wireless Sensor Networks (WSNs) have been recognized as very significant block of this inter-networking concept. Next-generation Internet enabled portable devices will set up advanced interactions with other devices and will make up the new Internet of Things and will result an omnipresent infrastructure[2]. Such a wide perception requires stable foundations, starting from a extensively agreed protocol and communication infrastructure, which is identified in the 6LoWPAN protocol suite[3]. 6LoWPAN is an significant enabling technology allows to combine newer and older Web services, as well as to support the IoT interaction paradigm. 6LoWPAN used to implement many IoT applications, since it replaces the Internet Protocol for communication. An example of application in Smart Lighting implemented and illustrated in[4]. Apart from that, it could be used to integrate different smart devices in health care to alert patient's information to the medical professionals[5], it could be used to monitor and control the power consumed by various home appliances[6]. This paper analyses the suitability of 6LoWPAN for Internet of Things.

2. Internet Protocol Address Space Increase

Internet Protocol (IP) is the communication protocol in the TCP/IP suite, which is normally used to do different functions like routing, delivering packets and determining packet structure. In 1974, when IP is introduced, it used 8 bits for addressing. And supported total number of two

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to the power eight IP addresses, i.e., only 256 addresses. After release of IPv4 in 1981, the number of addresses supported was two to the power 32 (4 billion, or 4.3×10^9, addresses). But IPv6, the latest version of intern protocol, dramatically increased the number of addresses (2^{128} = 340 undecillion, or 3.4×10^{38} total addresses). The increase in IP address space is depicted in Figure 1. The difference between IPv4 and IPv6 is essentially in the amount of bits allocated for purposes of addressing, which is depicted in Figure 2[7]. As expected, if the number of devices increases significantly in IoT, IPv6 addressing enables to address billions of things in the IoT through different addresses. And this is done through 6LoWPAN, which is IPv6 over Low Power Wireless Personal Area Network. This enables Internet Protocol could be applied to even minute (tiny) and low-power devices with limited capacity to participate in Internet of Things.

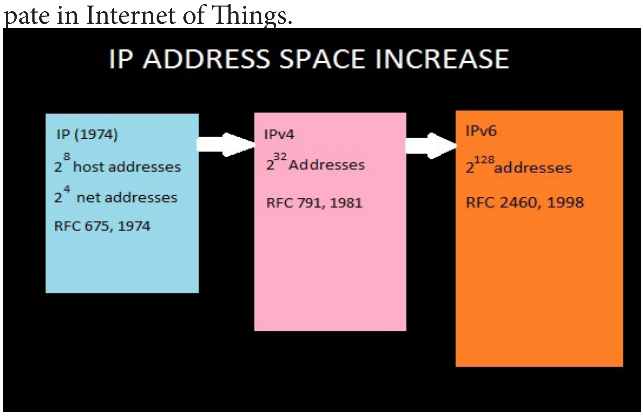

Figure 1. IP address space increase.

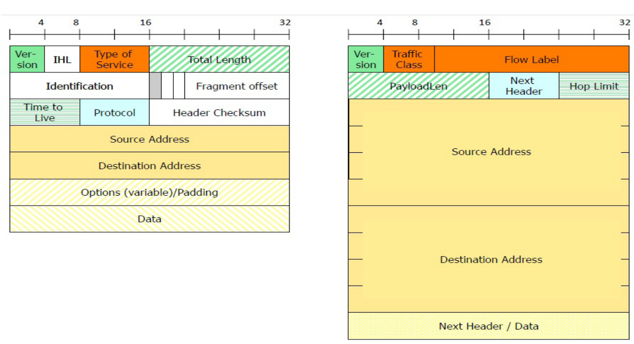

Figure 2. Header of IPv4 vs. IPv6.

3. Link Layer of 6LoWPAN

3.1 Link Layer

Internet protocol connects all sorts of heterogeneous links. Key features required by a link layer which is supported by internet protocol are framing, error checking, addressing, length indication, and the features of uni-casting and broadcasting. One example of link layer protocol is an Ethernet, the so called media access control layer shown in Figure 3(a). For purposes of wireless communications at low power, the IEEE standardization came up with 802.15.4 protocol which is an important standard for industrial control, home networking, and building automation. It has three physical layer modes, able to transmit at 20, 40, and 250 kilobits per second. It has a mode which supports very simple carrier sense multiple access algorithms. And it also has a bonfire mode which combines features of Time Division Multiple Access (TDMA), and Carrier Sense Multiple Access (CSMA) algorithms. The link layer supports up to 64,000 nodes, each of them with 16-bit address. And there are a number of extensions to that standard. Link layer is partitioned into 802.15.4 media access control and physical layer with 800 megahertz, 900 megahertz band, or 2.4 giga hertz band, both of which are overlaid with an upper layer stack shown in Figure 3(b).

3.2 Frame Size Vs Payload Size in 802.15.4 Link Layer Protocol

Many low power radio protocols expected to use very small frame sizes. So the frame size is dependent on the amount of payload or the data that need to carry and the amount of signaling data that is required to carry the packets. Figure 4 shows an example of 15.4 standard frame where the payload, the actual useful data, consists of 53 bytes where as the total number of bytes to carry this packet is 127 bytes. One should realize that the addition of header creates fairly large amount of overhead.

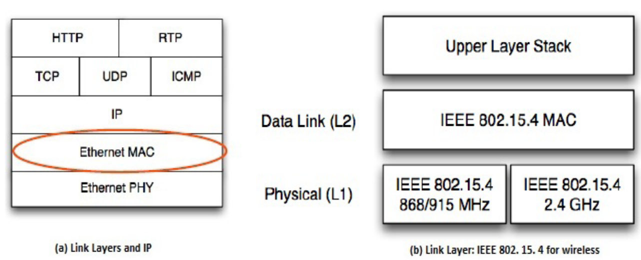

Figure 3. Link layer of 6LoWPAN.

4. Features of 6LoWPAN

The main features of 6LoWPAN are as follows: It supports 64 bit or 16-bit addressing. It's specifically targeted at low power radios, one of them being Bluetooth low energy or Bluetooth smart standard and it takes advantage of header compression for IPv base and as well as for UDP headers. 6LoWPAN uses network auto configuration for all participating devices, where each device is engaged in neighbor discovery. 6LoWPAN supports unicast, multicast, and broadcast and also the concept of fragmentation. The elementary size of a frame is 127 bytes taken from 15.4 standard and IPv6 transmission unit size is 1280 bytes. One needs to fragment 1280 bytes into a set of 127 byte frames, which is supported by 6LoWPAN. 6LoWPAN also supports IP routing. It supports a link layer mesh networking and supports security. A minimal 6LoWPAN protocol stack is shown on the right hand side of Figure 5, which comprises a traditional TCP/IP protocol stack[8–10]. Here the primary means of transport layer is UDP for 6LoWPAN. There is a specialized IPv6 with LoWPAN and it uses 15.4 media access control and physical layers.

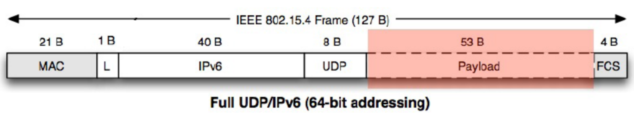

Figure 4. IEEE 802.15.4 frame.

5. Architecture of 6LoWPAN

Figure 6 depicts the architecture of 6LoWPAN. So-called ad-hoc LoWPAN illustrated down in Figure 6, which essentially means that that network is not connected to the rest of the internet. The next one is simple LoWPAN where a number of devices configured into one LoWPAN have a single edge router and that single edge router connects to the internet routers. The next one is extended LoWPAN where multiple LoWPAN devices have more than one edge router. And these edge routers are connected to a link, backbone link, which further makes it possible to connect to routers into the internet. So the edge router has a special functionality. It runs protocols which facilitate the changes required for traditional IP protocols to run towards the 6LoWPAN nodes[10].

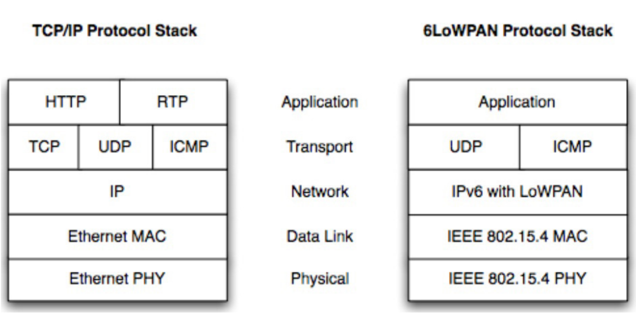

Figure 5. TCP/IP and 6LoWPAN protocol stack.

6. 6LoWPAN Addressing

6LoWPAN addressing is different from the ordinary IPv6 addressing. Essentially IPv6 addresses are compressed for purposes of 6LoWPAN. So LoWPAN works on the principle of having a flat address space which means that inside that wireless network there is only one IPv6 subnet within which it has unique media access control addresses. And these addresses are either 64-bit or 16-bit long. So the compression of IPv6 addresses is done by eliding the IPv prefix, compressing the IID (Interface Identifier), and by compression of multicast addresses. Essentially the global prefix is known by all nodes in the network and the link layer prefix is indicated by the header compression format. An example of addressing is shown in Figure 7. It has a core IPv6 internet network connected through a router and through an edge router which supports 6LoWPAN. From this point it is dealing with network addressing specific to the 6LoWPAN network. If one looks at this address of edge router, it is common to this whole network of 6LoWPAN.

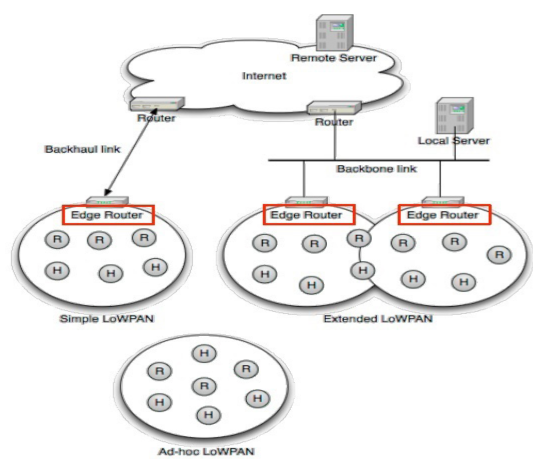

Figure 6. 6LoWPAN architecture.

6.1 Header Comparison in 6LoWPAN with 15.4 Standard

Header is changed in 6LoWPAN based on the definition in 15.4 standard and the comparison of 6LoWPAN header with 15.4 standard is depicted in Figure 8. The problem with 15.4 is only 53 bytes out of the 127 bytes are the useful for payload. But 6LoWPAN can minimize the header or to compress the header; there by making as many as 108 bytes contribute to the payload to the useful data. That indeed meant that the header was compressed. This is a critical feature of the 6LoWPAN. It is observed that the 40 bytes of IPv6 are not present down in Figure 8 for UDP/LoWPAN addressing[11]. An illustration of the traditional UDP/IPv6 is depicted in Figure 9, where quite a large portion of the packet is taken by the addressing for source and destination and the payload is very small, 6LoWPAN overcome this issue.

6.2 6LoWPAN Format Packet Fragmentation

The additional problem that needs to deal with is that the size of an IP packet is notably larger than the size of 15.4 standard packets. The difference is 1280 bytes is the Minimum Transmission Unit (MTU) for IPv6 where the useful amounts of data that can carry over 15.4 standard is only about 80 to 100 bytes. So the fragmentation has been defined as a concept of breaking the MTU into a larger number of smaller frames[11]. One should realize that once fragmentation is applied, it is indeed useful for communication over low power wireless mesh networks. However, fragmentation creates its own problems, in that the reconstruction of fragmenting packets may be error prone. If there is a loss of one fragment, the whole packet will be lost and then the whole packet will have to be transmitted where the packet is referred to MTU of IP. While the channels have relatively low bandwidth and fairly large delay, that's an additional issue. So whenever possible application protocols should attempt to avoid fragmentation by using compression or alternative protocols, if possible.

7. Setup and Operation of 6LoWPAN

6LoWPAN is auto configured.

7.1 Startup of 6LoWPAN

The sequence of steps for startup of 6LoWPAN is as follows.

Step 1. **Commissioning:** First the link layer connectivity is established between nodes.

Step 2. **Bootstrapping:** After which the network layer addressing is configured. The neighboring nodes are discovered. And the registration is completed.

Step 3. **Route Initialization:** Finally, the setup of routing algorithms is executed to complete routes.

Step 1 through Step 3 has to be continuously maintained.

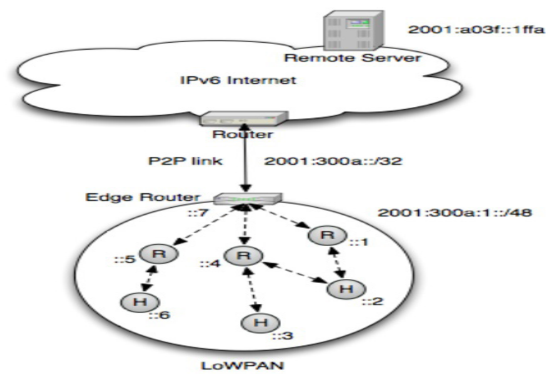

Figure 7. 6LoWPAN addressing.

7.2 Neighbor Discovery of 6LoWPAN

Standard Neighbor discovery used for IPv6 protocols is not appropriate for 6LoWPAN. The reasons being are that IPv6 assumes that all links have a single unique prefix. The other assumption is that all nodes are always on, which may not be true in 6LoWPAN. Heavy use of multicast traffic in IPv6 is not entirely easy to support by 6LoWPAN. And finally multihop is not efficiently supported over 15.4 standard which is used for 6LoWPAN. So neighbor discovery, which is used in 6LoWPAN, provides appropriate link and subnet model for all power wireless. It minimizes the control traffic between the nodes which are node-initiated. It provides node registration and node confirmation, recognition/detection of duplicate addresses and recovery from such problems, and it supports extended edge router infrastructures.

8. Security in 6LoWPAN

6LoWPAN supports security, which is increasingly important for IoT systems. Wireless radio waves in reality easily overheard and they have limited amount of processing power. So any system usually has three main security goals, its integrity, confidentiality, and availability. And all of these security goals are supported in 6LoWPAN essentially through three different layers, namely, application layer, media access layer, and network layer[12] shown in Figure 10.

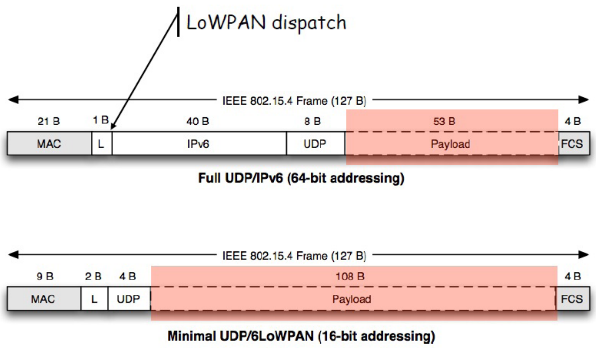

Figure 8. Header comparison of 6LoWPAN and 15.4 standard.

8.1 Security Mechanisms – Layer 2 (Media Access Layer)

Layer 2 (Media Access Layer), although that the internet security is usually thought of just end to end, in wireless networks the wireless channel itself is very vulnerable. It is easy to eavesdrop and it's easy to spoof packets or nodes. So at the data link layer we attempt to protect wireless network against attackers and increase the robustness against attacks. 15.4 standards provide for a built in encryption using128-bit AES (Advanced Encryption Standard) and its own encryption and integrity check called CCM (Counter with CBC-MAC mode). LoWPAN Chips that are being sold already include the hardware encryption engine for AES 128.

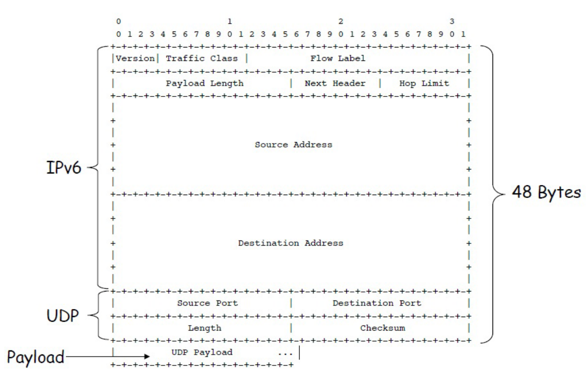

Figure 9. Headers for UDP/IPv6.

8.2 Security Mechanisms – Layer 3 (Network Layer)

At the layer 3 (Network Layer), the end to end security is provided by the IP. Essentially the entire path between the two endpoints is protected. Using the IPsec standard, there are two different types of packets or packet formats are defined. One of them called Authentication Header (AH), the second one called Encapsulating Security Payload (ESP). The authentication header is only concerned with integrity protection and authentication. And the ESP also encrypts the data for confidentiality. ESP is most widely used. And a particular version of ESP, a mode of ESP defines using AES/CCM is suitable for 6LoWPAN nodes. The hardware engine used for layer 2 in 15.4 can also be utilized for purposes of layer 3 security.

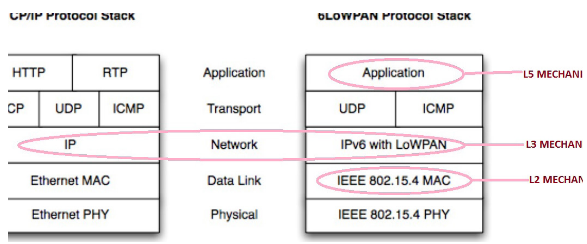

Figure 10. Layers providing security mechanism in 6LoWPAN.

9. Conclusion

By analyzing the architecture and other details of 6LoWPAN, many features revealed to prove its suitability for IoT. Link layer of 6LoWPAN could support tiny things to participate. Protocol stack of 6LoWPAN is appropriate for IoT. 6LoWPAN has many features like, support for 64 bit or 16-bit addressing targeted at low power networks including Bluetooth low energy or Bluetooth smart standard, header compression for IPv base as well as for UDP headers, network auto configuration and neighbor discovery, support for multicast, unicast, and broadcast, supporting the concept of fragmentation. There by, 6LoWPAN has mostly all the features of IPv6, but with handling tiny devices with limited processing capabilities. It is concluded that 6LoWPAN is a protocol that deals with constraint issues in Internet of Things systems and it is suitable for IoT.

10. Acknowledgement

The author expresses her deep gratitude for the support and motivation extended by the Management of IBS Hyderabad, IFHE University.

11. References

1. Gartner Says the Internet of Things Installed Base Will Grow to 26 Billion Units By 2020. Available from: http://www.gartner.com/newsroom/id/2636073

2. Castellani AP, Bui N, Casari P, Rossi M, Shelby Z, Zorzi M. Architecture and protocols for the internet of things: A case study. 2010 8th IEEE International Conference Pervasive Computing and Communications Workshops (PERCOM Workshops); 2010 Mar-Apr. p. 678–83.
3. Shelby Z, Borman C. 6LoWPAN: The wireless embedded internet. Wiley; 2009 Nov.
4. Huang Z, Yuan F. Implementation of 6LoWPAN and its application in smart lighting. Journal of Computer and Communications. 2015 Mar; 3:80–5.
5. Prakash M, Gowshika U, Ravichandran T. A smart device integrated with an android for alerting a person's health condition: Internet of Things. Indian Journal of Science and Technology. 2016 Feb; 9(6):1–6.
6. Sindhuja P, Balamurugan MS. Smart power monitoring and control system through internet of things using cloud data storage. Indian Journal of Science and Technology. 2015 Aug; 8(18):1–7.
7. Schonwalder J. Internet of things: 802.15.4, 6LoWPAN, RPL, COAP; 2010 Oct.
8. Shelby B. 6LoWPAN: The wireless embedded internet. John Wiley and Sons Ltd; 2009 Oct.
9. Olsson J. 6LoWPAN demystified, Texas Instruments. Available from: http://www.ti.com.cn/cn/lit/wp/swry013/swry013.pdf
10. Overview for 6LoWPAN. Available from: http://www.ti.com/lsds/ti/wireless_connectivity/6lowpan/overview.page
11. Ott A. Wireless networking with IEEE 802.15.4 and 6LoWPAN. Embedded Linux Conference; Europe. 2012 Nov. p. 1–60.
12. Mazzer Y, Tourancheau B. Comparisons of 6LoWPAN implementations on wireless sensor networks. Proc of 3rd International Conference on Sensor Technologies and Applications SENSORCOMM; 2009 Jun. p. 689–92.