Network protocol for Internet of Things based on 6LoWPAN

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Abstract

The four-layer network protocol architecture for Internet of Things is proposed based on 6LoWPAN, and the M/I adaptation layer, as the key of the protocol architecture, achieve the integration between underlying networks and Internet. MAC sublayer implement periodic listen/dormant mechanism and carry out unslotted CSMA/CA protocol in condition, and simultaneously fragmentation and reassembly of link frame header is used for link MAC packet. IP sublayer implements EHC scheme which could compress IPv6 global address header, and a IPv6 address auto-configuration method is proposed in IP sublayer. The test results indicate that the network architecture is well for large-scale Internet of Things and related methods save the network energy and improve the system throughput.

Keywords

6LoWPAN; Network Protocol; WSNs; Internet of Things.

1. Introduction

The Internet of Things (IoTs) has two key ideas. One is that Internet is the core and foundation of IoTs and the other is everything becomes terminal users that could communicate with each other. IoTs has three primary application processes: (1) Identify the objects properties. Static property information is saved in RFID tag [1], and dynamic property information need to be detected by sensors all the time [2]. (2) Recognition equipment read the object information and transform into data format by the requirement of networks. (3) Object information is transferred into information processing platform by networks, which completes related application calculation [3].

However, an important challenge for IoTs is the integration between Internet and the underlying heterogeneous networks [4]. IEEE 802.15.4 is a short-distance wireless network communication standard. IPv6 is the dominant technology in the next generation Internet network layer. 6LoWPAN (IPv6 over Low power Wireless Personal Area Networks) defines how to carry IPv6 packets over IEEE 802.15.4 low power networks. As shown in Fig.1, this paper defines M/I (MAC/IP) adaptation protocol architecture for IoTs based on 6LoWPAN, and focuses on the design of M/I adaptation layer that embed IPv6 into IEEE 802.15.4.

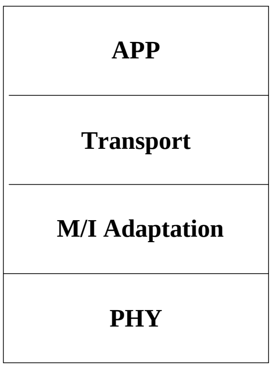


Fig.1. IoTs M/I adaptation protocol architecture

2. 6LoWPAN Background

The 6LoWPAN Work Group introduces an adaptation layer between data link and network layer, which realizes transmission of IPv6 Packets over IEEE 802.15.4 Networks. As we known, the data units on the Internet are transmitted by packets, so the IP packets become the data of MAC frame when it is sent to MAC layer. However, MAC protocol requires maximum length of data portion of the frame, MTU (Maximum Transfer Unit). Moreover, starting from a maximum physical layer packet size of 127 octets and a maximum frame overhead of 25, the resultant maximum frame size at the MAC layer is 102 octets. If starting Link-layer security, it imposes further overhead. This is obviously far below the minimum IPv6 packet size of 1280 octets. Thus, IEEE 802.15.4 MAC frame cannot encapsulate whole IPv6 packet [5-6].

3. MAC Sublayer Design

Compared with traditional computer network, the IoTs has characteristics of low power, low rate, low cost and large scale. Therefore, the traditional network MAC protocol cannot directly applied to the IOT. We adopt a new CSMA/CA protocol as MAC sublayer access protocol of the IoTs.

The basic mechanism describes as follow: nodes in the network use a periodic listening/dormant mechanism to reduce energy consumption. After the dormancy, a node will immediately change into dormant state if there is no activation events occurred that need the node to continue to work within the IFS (InterFrame Space).

When the node receives the signal of activation event, it will immediately switch to listening state, and then prepare to send date frame. Simultaneously it implements non-slotted CSMA/CA protocol conditionally. Periodic listen / dormant CSMA / CA protocol scheme is shown as Fig.2.

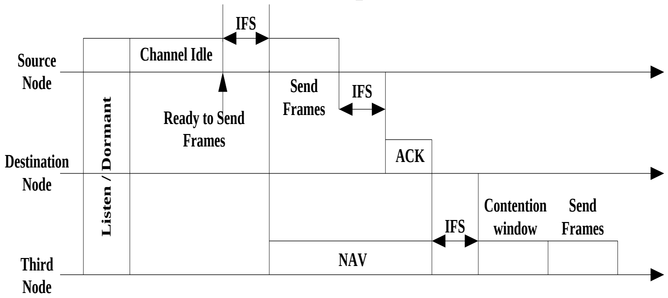


Fig.2. Periodic listen / dormant CSMA / CA protocol scheme

If the payload submitted by IP sublayer protocol is larger than that of MAC sublayer MTU, the source node will split the payload, and needs to use the fragment header to provide reassembly information. The first and the subsequent fragmentation header structures are shown as Fig.3 and Fig.4.

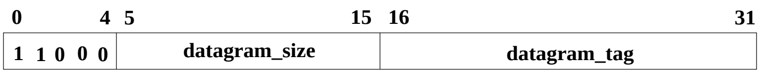


Fig.3. First Fragment

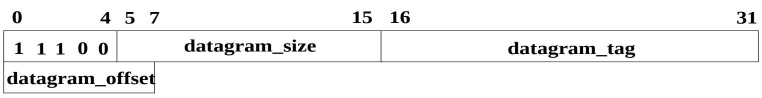
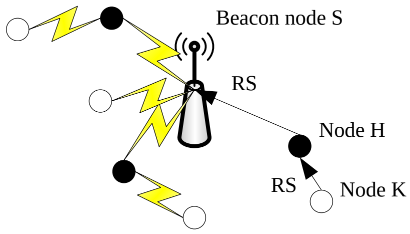


Fig.4. Subsequent Fragments

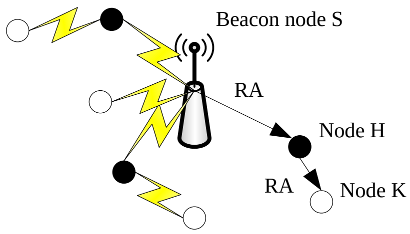
4. IPv6 Address Auto-configuration

For 64-bit long address, its 64-bit extension identifier forms interface identifier (ID) of IPv6 address. The seventh bit in the first 24 manufacturer identification in IEEE EUI-64 is U bit, namely, unified/local (U/L), where U=1 expresses local administered address mode, U=0 expresses unified administered address mode; the eighth bit is I bit, namely, Unicast/Multicast (I/G), I=1 expresses multicast, I=0 expresses Unicast.

As shown in Fig.5, in order to obtain global routing prefix, the node K needs to send RS (Route Solicitation) to its adjacent beacon node S; the source address of the RS messages is the link local addresses of the node K, and the destination address is the Multicast address of the beacon node S. After receiving the RS message of the node K, the beacon node S will return a RA (Router Advertisement) to the node K, the source address of RA message is IPv6 address of the beacon node S, and the destination address is the link local address of the node K. Meanwhile, the option field of this RA message will provide the global routing prefix. After obtaining the global routing prefix, a global IPv6 address is formed by the node K that combines with the interface identifier. So far, address auto-configuration process of the sensor nodes is completed.



Route Solicitation
(a)



(b) Router Advertisement
Fig.5. Route Solicitation and Advertisement

5. Simulation Experiment

For the M/I layer application, we use Xi'an Huafan Technology HFZ-CC2430ZDK microcontroller model, with a single-chip 2.4 GHz RF transceiver (CC2430-F128 chipset). It also includes 128K Bytes ROM, 4K Bytes RAM. The PAN nodes are connected through the PPP interface to the Beacon node. We build implementation testbed over M/I stack. The devices support AODVjr and Cluster-Tree routing protocol.

The M/I Beacon node is the gateway that is connected to Internet. In addition, the Beacon node is coupled with the other nodes within the network by 16-bit short address. After initialization its address is 0. All the nodes form the network based on the Beacon node.

We use testbed described above to evaluate the network throughput compared with 6LoWPAN at first. Fig.6 shows the average system throughput under the two cases along with the increasing data payload. From the Fig.6, M/I has improved about 40% in throughput compared with 6LoWPAN, which is the important advantage of this protocol. Secondly, the experiment testifies the reliability of the M/I protocol from the perspective of energy consumption. From Fig.7, the energy consumption increases linearly with the increase of data payload bytes, but it is always maintained at the level of 0.1mJ. Even though transmission payload achieves maximum bytes for 127, the energy consumption still remains within the 1mJ; while the typical wireless communication protocol including 6LoWPAN needs to consume several mill joules in variety when it transmits one byte. Therefore, the improved light network protocol reduces the energy consumption, which lays the foundation for large-scale popularization of the IoTs.

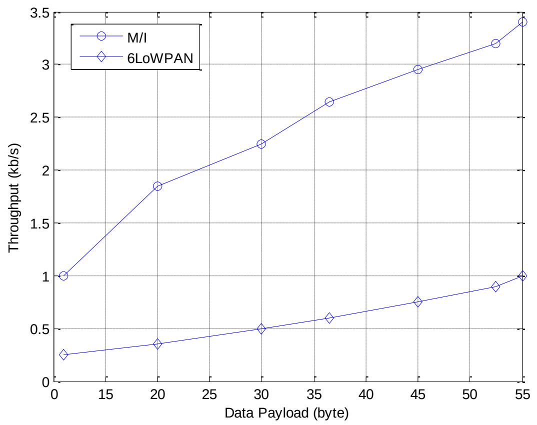


Fig.6. Throughput Analysis

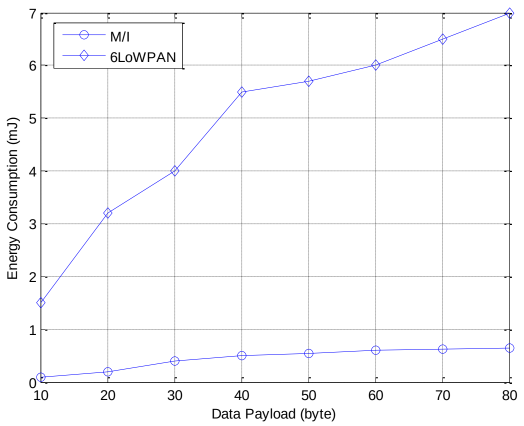


Fig.7. Network Protocol Energy Analysis

6. Conclusion and Future Works

On the basis of analyzing the problems for 6LoWPAN that develop future IoTs, the paper proposes the three-layer network protocol architecture which is the same with IoTs: Application layer, M / I layer and Physical layer. By researching on M/I layer, the paper proposes MAC sublayer protocol solution and link frame header fragmentation method, IP sublayer header compression scheme. Simulation results show the network protocol fits for large-scale popularization of the Internet of Things. However, there are many uncertainties for large-scale popularization of the Internet of Things, and many technical aspects that need to be broken through [7]. Therefore, we plan to perform further experiments in WSN time synchronization and Ubiquitous Network Protocol.

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