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SERIES L: CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

Reference operational model and interface for improving energy efficiency of ICT network hosts

Recommendation ITU-T L.1321

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Summary

Recommendation ITU-T L.1321 describes a reference operational model and interface for improving energy efficiency of ICT network hosts. The operational model and interface specify network proxy operation to support IPv4 ARP and DHCP in order to promote the deployment of network proxy.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T L.1321	2015-03-01	5	11.1002/1000/12429

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

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Reference operational model and interface for improving energy efficiency of ICT network hosts

1 Scope

This Recommendation specifies a reference model for improving energy efficiency of wired network hosts so that network hosts can reduce energy consumption by entering an energy saving sleep state. This Recommendation describes the specification for improving energy efficiency by defining a reference operational model of a network proxy to handle mandatory protocols for network hosts in the sleep state.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T Y.3021] Recommendation ITU-T Y.3021 (2012), *Framework of energy saving for future networks.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following term defined elsewhere:

3.1.1 network proxy [b-ECMA 393]: An entity that maintains network presence for a sleeping higher-power host.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 host: An entity that uses a network proxy functionality for maintaining network presence in a lower power state.

3.2.2 sleep: The state in which the host uses less energy than it does when fully operational.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

ACK Acknowledgement

ARP Address Resolution Protocol

DHCP Dynamic Host Configuration Protocol

ICMP Internet Control Message Protocol

ICT Information and Communication Technology

IP Internet Protocol

LAN Local Area Network

MAC Media Access Control

NACK Negative ACK

NIC Network Interface Card

UDP User Datagram Protocol

5 Conventions

None.

6 Reference operational model and interface for improving energy efficiency of ICT network hosts

6.1 Overview of energy management for ICT network hosts

The information and communications technology (ICT) sector is facing rapid growth and consuming a lot of power in order to provide large bandwidth and complex application services. According to [b-ITU-T CC Report], wired and wireless networks consume large amount of power and the amount of green-house gas emissions caused by ICT sector is estimated 2% of total man-made emissions. It is also estimated that network sector, including network equipment and equipment connected to networks, contributes 4% of world power consumption. Further, it is observed that the power consumption is higher at access networks and users, so how to reduce the power consumption in these areas is becoming an important issue. According to recent surveys, network equipment shows a constant power consumption profile irrespective of their utilization level, i.e., an energy-agnostic power profile. Such equipment represents the worst case in terms of utilization and power consumption profile. On the contrary, ideally, energy-aware equipment represents a power consumption pattern proportional to their utilization or offered load. Practical approaches for realizing the energy-aware equipment are implementing multi-stepped power profiles in order to adapt to the utilization level [b-IEEE Computer] [b-IEEE Comm Sur] [b-IEEE 802.3az].

There is another research direction for improving energy efficiency of network equipment using network proxy technology [b-IETF EEI] [b-ECMA 393] [b-IEEE IPCCC]. Network proxy describes technologies that maintain network connectivity on behalf of other devices so that these can go into low power sleep states. This mainly targets the reduction of unnecessary energy waste through edge devices.

There are typically two types of network proxies: internal and external, respectively.

- Internal Proxy: proxy functionality is implemented within the ICT equipment such as network interface card.
- External Proxy: proxy functionality is placed within other network equipment such as a switch or external server in a network.

The European Computer Manufacturers Association (ECMA) International has published specification [b-ECMA 393] that describes an overall architecture for network proxies and provides capabilities that a proxy may expose to a host. Also, information that must be exchanged between a host and a proxy, and required and optional behaviour of a proxy during its operation are described. A generalized network proxy is capable of providing full network presence for a broad range of network protocols and applications. The generalized network proxy includes a list of packet types that may require routine reply, auto-generation, and wakeup, as well as the detailed steps and methods for state information transfer each requires [b-Ether Alliance].

It is well known that many network hosts are in an active state in order to maintain network presence and this behaviour hinders hosts from entering an energy saving state. Even when a node is idle with no running applications, background traffic is received and processed, which inhibits the node from sleeping. The use of a network proxy is one of the possible solutions to resolve this issue. The general framework for a network proxy was developed, but the control interface and operational model between network hosts and network proxies to handle incoming packets destined to network hosts in sleep state have not been developed. Thus, in order to promote the wider deployment of the network proxy mechanism, the control interface and operational model of a network proxy to handle protocols on behalf of network hosts in sleep state should be specified.

This Recommendation describes a reference operational model and interface that is needed for communication between a network proxy and network nodes. The interface and operation model for network proxy operation and relevant messages can be used to increase energy efficiency of network hosts.

6.2 Reference operational model for delegating network connectivity maintenance

Network proxy refers to a set of mechanisms dedicated to put network interfaces and network hosts into an energy saving sleep state, which is a management method used by energy efficient network hosts. Energy consumption of network host in a sleep state is less than in an active state in general, so the longer the sleep period, the higher the achievable energy saving can be. A network proxy is a technology that delegates some networking functions in network hosts to other network elements such as external nodes or other modules in the nodes. The network proxy enables the network hosts to maintain network connectivity during the sleep state. Figure 1 shows the typical operational scenario of network proxy. When a sleeping host wants to enter energy saving sleep state, the host delivers its network status and state to a network proxy and goes into sleep state. Then, the network proxy responds to periodic messages on behalf of the host in the sleep state. If the proxy receives a message that it cannot process, it sends a wake-up message to the host so that the host can process the message after wake-up.

It is noted that this Recommendation specifies the operational model and interfaces between a network proxy and other network nodes in Figure 1. The specification for operations between the sleeping host and network proxy are out of scope of this Recommendation.

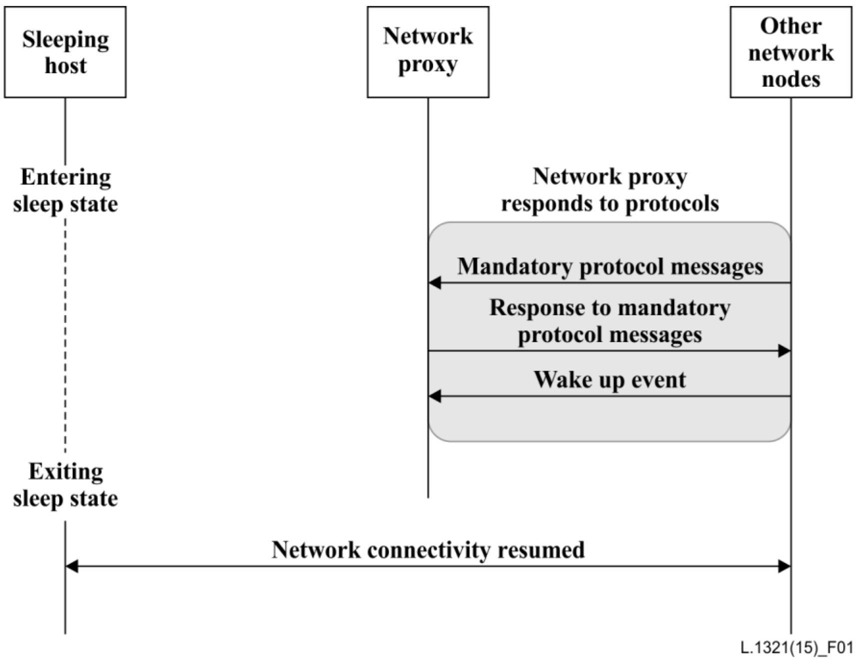

Figure 1 – Reference operational model for delegating network connectivity maintenance

6.3 Network protocols for network connectivity maintenance delegation

The following list summarizes the requirement status about what types of protocols a network proxy should support [b-ECMA 393]. Among them, this Recommendation describes address resolution protocol (ARP) and dynamic host configuration protocol (DHCP) related operation as mandatory protocols for rapid deployment.

- Mandatory 1: Media (IEEE 802.3) – [b-IEEE 802.3]
- Mandatory 2: IPv4 ARP – [b-IETF RFC 826]
- Mandatory 3: Wake packets – [b-Magic Pkt]
- Mandatory 4: DHCP – [b-IETF RFC 2131]

Regarding wake packets among mandatory protocols, this Recommendation recommends to use "Magic Packet" over UDP. It broadcasts a UDP packet containing synchronization stream and the target MAC address of sleeping host. The synchronization stream is expressed as a six-byte hexadecimal value. After that, 16 duplications of the target MAC address are appended. The packet format of "Magic Packet" over UDP is as follows:

- Destination IP address: 255.255.255.255
- UDP data: 0xFF FF FF FF FF FF [Target MAC × 16 duplications]

Those mandatory protocols are typically used within local area network (LAN) environment, so this Recommendation is applicable to a LAN environment. Extending the applicability of this Recommendation to other environment such as enterprise networks and wide area networks are not within the scope of this Recommendation and extending the applicability requires further investigation on security and network administration issues.

7 Operation interface for energy efficient network host management

7.1 Operation interface for network host management

Figure 2 depicts network proxy operation for IPv4 ARP. A sleeping host performs discovery procedures to detect the network proxy and proxy capability. After the discovery procedure, the host and discovered network proxy exchange ARP configuration information including the host's media access control (MAC) address(es) and IP address(es) so that the host can enter a sleep state. Then the network proxy discards ARP Request messages broadcast from other nodes in the network. By doing so, the sleeping host can sleep without receiving or processing ARP broadcast message not destined to the sleeping host itself. If the network proxy receives an ARP request message for the sleeping host, it sends a wake packet to wake up the sleeping host. Since IP packets are followed by ARP request message that resolves the sleeping host's IP address and MAC address, the network proxy initiates a wake-up procedure on receiving an ARP request message for the sleeping host in order to reduce the delay in wake-up and network connection recovery time of the sleeping host. After exiting the sleep state, the sleeping host can process the incoming packets.

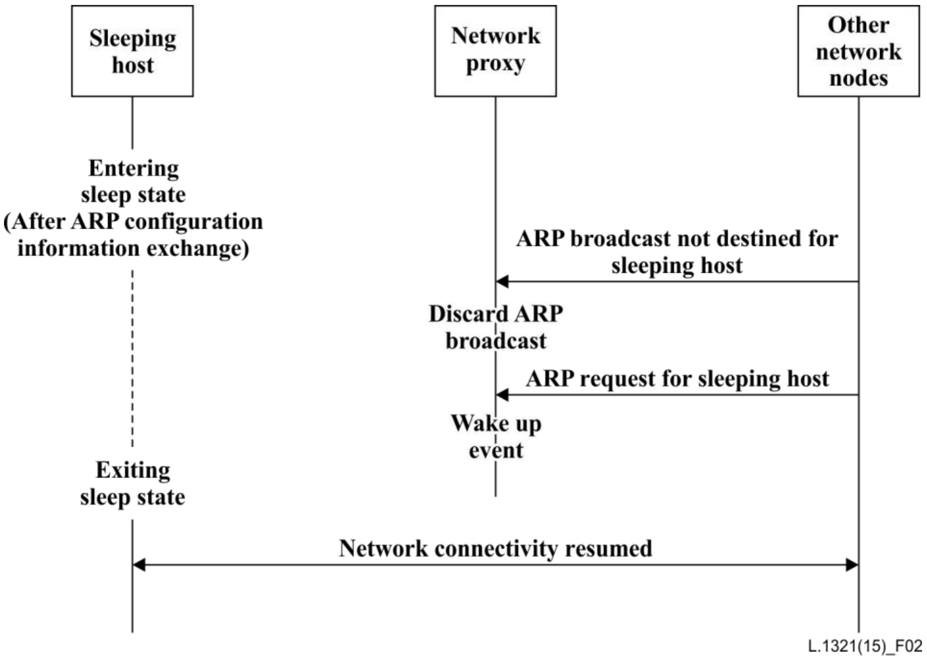

Figure 2 – Network proxy operation for IPv4 ARP

Figure 3 depicts network proxy operation for DHCP. After the network proxy discovery procedure, the sleeping host and network proxy exchange the host's DHCP-related parameters including the IP address of DHCP server, DHCP total lease time and DHCP remaining lease time. Then, the host enters sleep state. When 50% of DHCP total lease time for the sleeping host expires, the network proxy sends DHCP Request message to the DHCP server and tries to renew the DHCP lease time on behalf of the sleeping host. In case of successful DHCP renewal, the sleeping host can maintain the sleep state. When the sleeping host wakes up, the network proxy and the sleeping host exchange information for DHCP lease time.

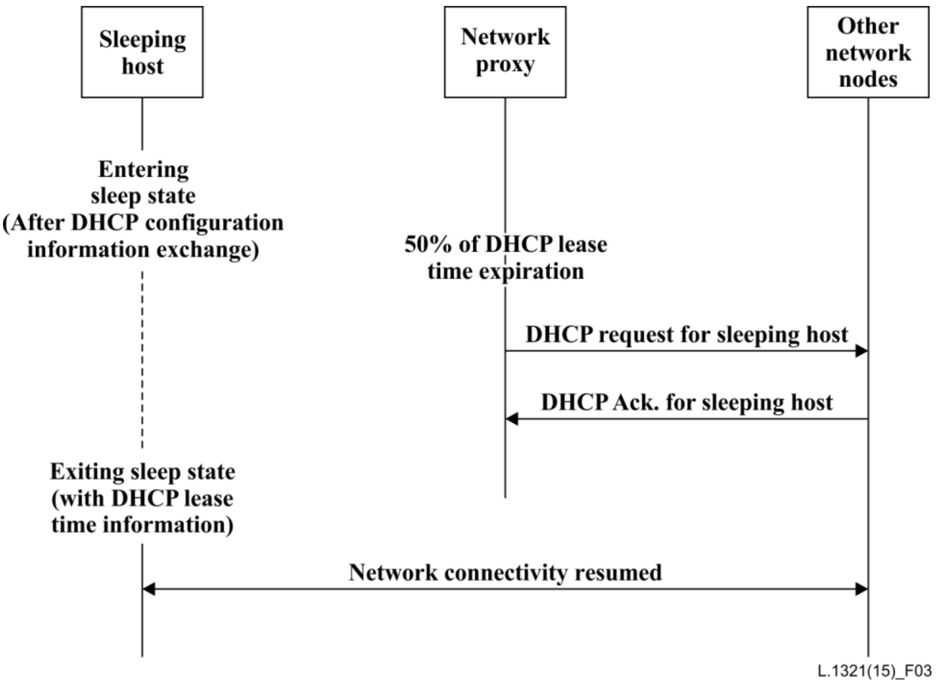

Figure 3 – Network proxy operation for DHCP renewal success

When the network proxy fails to receive a DHCP acknowledgement message in response to a DHCP request message at the time of 50% of DHCP lease time expiration, the network proxy sends a DHCP request message at the time of 87.5% of DHCP lease time expiration as shown in Figure 4. If the network proxy still fails to receive a DHCP acknowledgement message confirming the renewal of DHCP lease time, the network proxy initiates the wake-up procedure by sending a wake packet to the sleeping host at the time of DHCP lease time expiration or receiving DHCP NACK message. When the sleeping host wakes up, the network proxy delivers the current DHCP state information to the sleeping host so that the host can perform the relevant DHCP operation.

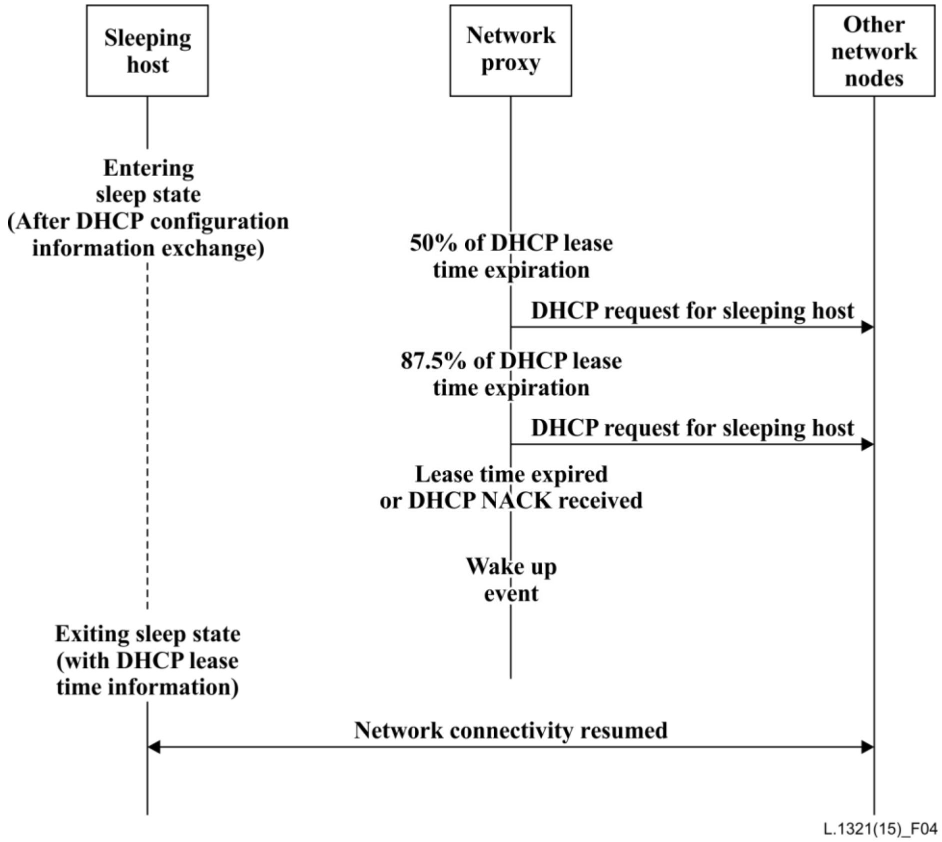

Figure 4 – Network proxy operation for DHCP renewal failure

8 Security considerations

A network proxy allows delegating the functionality for maintaining network connectivity in network hosts to network proxy in networks. Thus, there is a possibility for security threats when using the network proxy technology. For example, a compromised network proxy in networks may cause security problems in network hosts using proxy functionality. Therefore, it is recommended to apply security mechanisms to ensure authentication and authorization between a network host and a network proxy.

Bibliography

[b-ITU-T CC Report] ITU Report (2008), *ITU and Climate Change*.

[b-ECMA 393] ECMA International ECMA-393 (2012), *ProxZZZy for sleeping hosts*.

[b-IEEE 802.3] IEEE 802.3-2012, *IEEE Standard for Ethernet*.

[b-IEEE 802.3az] IEEE 802.3az-2010, *IEEE Standard for Information technology – Local and metropolitan area networks – Specific requirements – Part 3: CSMA/CD Access Method and Physical Layer Specifications Amendment 5: Media Access Control Parameters, Physical Layers, and Management Parameters for Energy-Efficient Ethernet*.

[b-IEEE Computer] L.A. Barroso and U. Hölzle (2007), *The Case for Energy-Proportional Computing*, IEEE Computer, vol. 40, pp. 33-37, Dec.

[b-IEEE Comm Sur] Aruna Prem Bianzino, *et al.* (2010), *A Survey of Green Networking Research*, IEEE Communications Surveys & Tutorials, Vol. 99, pp. 1-18.

[b-IEEE IPCCC] Jimeno, M., Christensen, K., and B. Nordman (2008), *A Network Connection Proxy to Enable Hosts to Sleep and Save Energy*, Proc. IEEE Internat. Performance Computing and Communications Conf.

[b-IETF EEI] Winter, R., Jeong, S., and J. Choi (2012), *Towards an Energy-Efficient Internet*, draft-winter-energy-efficient-internet-01 (work in progress).

[b-IETF RFC 826] IETF RFC 826 (1982), *An Ethernet Address Resolution Protocol*.

[b-IETF RFC 2131] IETF RFC 2131 (1997), *Dynamic Host Configuration Protocol*.

[b-Ether Alliance] Ethernet Alliance (2007), *Improving the Energy Efficiency of Ethernet-Connected: A Proposal for Proxying*.

[b-Magic Pkt] AMD White Paper (1995), *Magic Packet Technology*.

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