

Design of UPnP based Cooperative Network Connectivity Proxy

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Abstract—The Internet connected edge devices require active participation by generating and responding to routine applications/protocols heart-beat messages. Failing to do this will result in loss of their presence over the Internet. A huge amount of energy is wasted every year to keep idle or unused network hosts powered-up 24/7 only to maintain the network presence for remote access, file sharing and other administrative management reasons. Thus, reducing the energy waste of ICT is becoming increasingly important due to rising costs of electricity, limited natural resources and environmental concerns. This extended abstract presents a new design of cooperative Network Connectivity Proxy (NCP) to reduce the network energy consumption. The NCP uses a low power entity that can maintain the network presence for the high power devices and smartly allows them to transition into low power sleep/active modes. The Universal Plug and Play (UPnP) protocol, that allows seamless discovery and communication between the network hosts can be well-suited approach for the design of NCP. All the hosts in the local network can seamlessly interact and use the services offered by the NCP. The UPnP based NCP includes a connectivity management service that implements the key network presence and management protocols like DHCP, ICMP, ARP etc. Thus, the NCP can reduce the network energy consumption by 60 to 70% depending on the network host's time usage model.

Index Terms—Green networking, power management proxy, energy efficiency, Universal Plug and Play.

I. INTRODUCTION

The amount of energy consumed by the Internet connected edge-devices is increasing rapidly due to the continuous increase in the number of edge-devices, high data rates and rapid increase in the number of services offered by telcos and Internet Service Providers (ISPs). The Global e-Sustainability Initiative (GeSI) estimated overall network energy consumption for the European telcos and ISPs of about 21.4 TWh in 2010 which is expected to increase upto 35.8 TWh by 2020 if no green networking technology is adopted [1]. A single 80W PC can add about 6.5% to the utility bill for a typical household if remains powered-up 24/7 [2]. The Environmental Protection Agency (EPA) estimated that personal computers (PCs) consumes about 2% of the overall US electricity requirement [3]. Thus, one of the key challenge for the 21st century is the adoption of green networking technologies to step into a sustainable society with reduced CO_2 footprint [4].

A recent study has revealed that about 60% of the office computers are left powered-up 24/7 with the existing power

management features disabled only to maintain the network connectivity for remote access, Voice-over-IP (VOIP) clients, P2P networking, Instant Messaging (IM) and other administrative management reasons [5]. The Advanced Configuration and Power Interface (ACPI) has defined several power management states but unfortunately, none of the power management states can maintain the network presence. Thus, a huge amount of energy is wasted every year to keep idle/unused network hosts powered-up for the sole purpose of maintaining network presence.

This extended abstract presents a new approach for the design of cooperative Network Connectivity Proxy (NCP) in order to reduce the network energy consumption. The NCP is a software entity implemented on a low power device that can maintain the network presence on behalf of high power devices and allows them the sleep when idle [6]. The NCP performs the key network presence and management tasks on behalf of sleeping network hosts and wakes them only when their resources are required. It implements a packet classifier that determines the type of action upon receiving each incoming packet for the sleeping network hosts. The Universal Plug and Play (UPnP) protocol can be well-suited approach for the design and implementation of NCP. The UPnP is getting increasing popularity for the local networks due to the seamless configuration ease that it offers. Also it can be implemented on a number of network based devices e.g., PCs, printers, scanners, Internet gateways, mobile portable devices, etc for offering their services and communicate in a seamless way [7]. The UPnP technology is vendor independent and uses a set of protocols that allow network hosts to seamlessly discover and interact with one another [8]. The main objective of this extended abstract is to describe the design of NCP using UPnP technology that can be easily implemented inside a residential Home Gateway (HG) e.g., ADSL switch/router and offers power management service to all the hosts in the local network.

II. OVERVIEW OF UPNP

The UPnP technology is designed to provide easy-to-use, flexible and standard based seamless communication between the network devices. It supports zero-configuration and invisible networking and can be implemented on a wide range

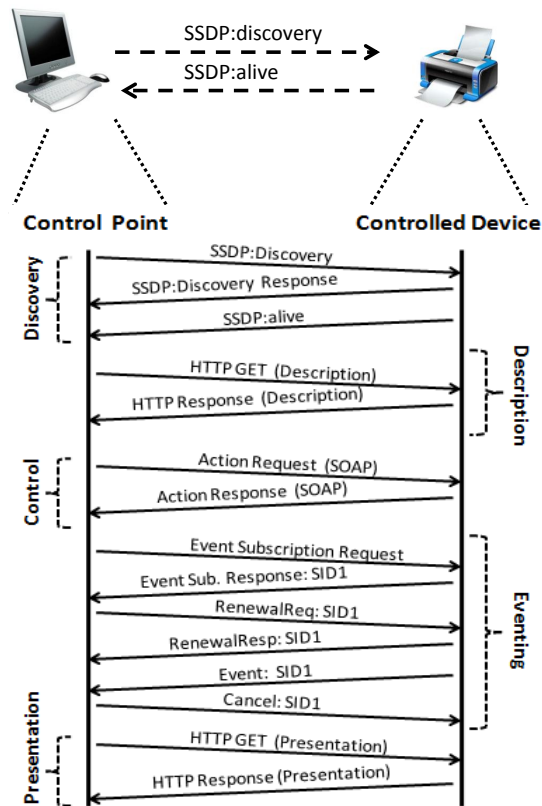


Fig. 1: Generic UPnP scenario.

of device categories from different vendors [7]. It is getting increasing popularity for its deployment in the residential networks and allow seamless communication between the network devices. The UPnP concept is basically the extension of PC peripheral Plug and Play concept to the network. A UPnP device can dynamically join the network, advertise its services and capabilities and seamlessly learn about the presence and capabilities of other network devices. The UPnP standard also allows the devices to leave the network smoothly without leaving any unwanted states behind.

UPnP uses the concept of control point (CP), controlled device (CD) (or simply device) and service. Service is a logical functional unit that receives instructions from the CP. It exposes possible actions to the CP and models the state of the physical device with the state variables. CP retrieves the CD and service descriptions, sends actions to the services implemented by the CD, calls the service state variables and receives event notifications from the services. CD is a physical entity that implements one or more services and periodically advertises its presence over the network. It may also embed other logical devices [7].

The UPnP protocol work flow can be briefly addressed in the following steps.

- 1) *Addressing*: The UPnP device gets an IP address.
- 2) *Discovery*: UPnP CD uses Simple Service Discovery Protocol (SSDP) to advertise its services to the CP. Similarly, the CP also uses SSDP to find the CD of interest.

- 3) *Description*: The CP retrieves the CD and service descriptions from the URL provided by the device in the discovery message. The description is expressed in XML file that contains complete information about the CD.

- 4) *Control*: The CP uses Simple Object Access Protocol (SOAP) to send an action to the services offered by the CD. The control messages are expressed in the XML format.

- 5) *Eventing*: The action performed in response of control messages may causes change in the state variables value. Service uses eventing messages to publish updates about these state variables. Eventing messages are also expressed in XML format.

- 6) *Presentation*: The CP retrieves the CD information page from the presentation URL of the CD which may allow users to control and/or just view the CD status.

Fig. 1 shows an example of a UPnP printer. The printer implements the printing service that receives instructions from CP implemented on the network device such as PC. The UPnP CD sends periodically SSDP:alive messages that are valid for a short period. The CP also uses SSDP:discovery multicast requests to discover services in the CD [8]. Both CP and CD can be implemented on any platform like PCs and embedded systems.

III. NETWORK CONNECTIVITY PROXY

The NCP can result in considerable amount of energy savings by maintaining the network presence for the sleeping hosts and allows them to sleep when idle. The NCP wakes up the host only when its resources are required [2] by using Wake On LAN (WOL) packet (also known as magic packet). All modern NICs have the capability of pattern matching and trigger wake up on receiving the WOL packet.

A. Overview of NCP

The quite generic functional diagram for the NCP is shown in Fig. 2. The host transfers its network presence state to the NCP before it enters into sleep mode. The NCP starts performing on behalf of sleeping network host by generating/responding to routine applications/protocols heart-beat messages. It wakes up the host when it receives a packet that requires host resources e.g., new TCP connection request. After the host fully wakes up, the NCP transfers back the presence to the host. The NCP performs the following basic tasks on behalf of sleeping host.

- 1) It maintains the MAC level reachability of the sleeping network host by generating/responding to the ARP request packets.
- 2) It maintains the network level reachability of the sleeping network host by maintaining the presence of host IP address in the network. It accomplishes this task by sending periodic DHCP lease requests and by generating/responding to network presence messages e.g., ICMP echo requests.
- 3) It maintains the application-level reachability of the sleeping network host by generating/responding to application level heart-beat messages.

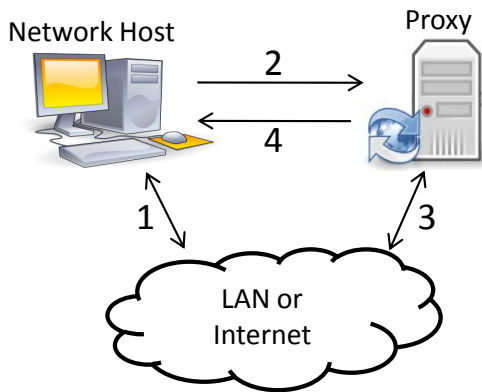


Fig. 2: NCP overview: 1:host awake, 2:host going to sleep, 3:proxy performs on behalf of host, 4:host wake up.

B. Design of Cooperative Network Connectivity Proxy

Generic UPnP design has CP and CD implemented on two different network entities. CP sends control messages to invoke a specific action implemented by the service inside the CD. The CD informs the CP about the result of the action and state variables value. In UPnP based NCP design, both host and proxy implement CP as well as CD with logical services. Fig. 3 shows the generic design for UPnP based NCP. The proxy functionality can be implemented on a low power network entity e.g., gateway router/switch and has the capability to maintain the presence for high power network devices like PCs. Proxy CP can invoke the actions implemented by the power management service inside CD of the network hosts. Network hosts CD implement actions that can control the hosts power state according to the UPnP low power specification. Similarly, network hosts CP can invoke the actions implemented by the network connectivity management service inside CD of the proxy. Proxy CD implements actions that can activate different network presence and management capabilities for the network hosts. These actions may include:

- 1) *Wake-On-Connection*: Wake up the sleeping host on a new connection attempt at specific protocol and port.
- 2) *Wake-On-Packet*: Wake up the sleeping host on receiving a specific packet.
- 3) *Send-Reply-On-Packet*: Send reply on receiving a specific packet e.g., ICMP echo request, ARP request etc.

IV. CONCLUSIONS AND FUTURE WORK

This extended abstract has described the ongoing research work in the design of NCP using UPnP. UPnP is getting increasing popularity due to its seamless configuration ease, thus it can be consider as well-suited approach for the design of future NCP. Furthermore, the UPnP based NCP concept for PCs can be extended easily for the power management of other UPnP based network devices e.g., printers, scanners, etc. Future research will focus on the implementation of UPnP based NCP that will also embed the capabilities to preserve open applications or TCP connections on behalf of sleeping network hosts. Due to large number of network

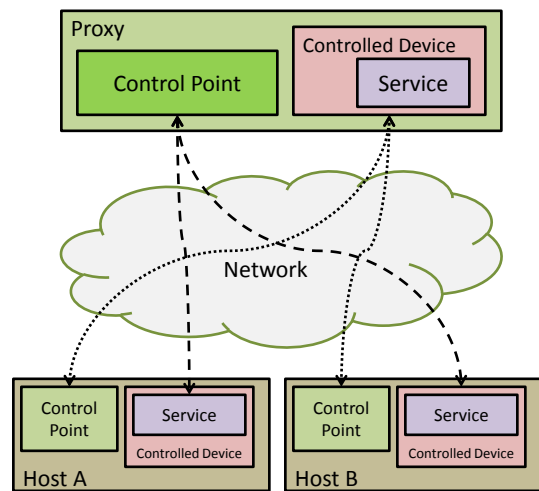


Fig. 3: UPnP based NCP design.

based applications that are continuously increasing, the future research will also focus to make NCP application independent. The NCP can result in significant network energy savings by maintaining the network presence for high power devices and allowing them to sleep when idle. The expected energy savings can be 60 to 70% depending on the network host's time usage model.

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