OSA-Based Service Platform for All-IPv6 Network Environments

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***Abstract*—The use of IP (Internet protocol) technology in the information and communications industry constitutes a major global trend. A highly efficient service architecture, enabling technologies and advanced applications are essential to rapid multimedia services in an all-IPv6 network environment. This work presents an all-IPv6 service platform based on open service architecture (OSA) to support a set of standard interfaces and applications. The all-IPv6 network environment was integrated using a network-processor-based IPv4/IPv6 translator and a mobile router (MR) supported IPv6 network mobility. The feasibility of the open service platform for all-IPv6 network environments and of the designed application programming interfaces was examined using three applications: e-commerce, video-on-demand, and on-line gaming. The performance analysis indicates that the system throughput increased from *10.5* to *60.5 Mb/s* as the number of users increased from *1* to *80*; the mean response time increased from approximately *1* to *10.5 ms*, and the delay time increased from *0.1* to *1 ms*.**

***Index Terms*—All-IPv6 networks, application programming interface (API), IPv4/IPv6 translator, Java APIs for integrated networks (JAIN) platform, network mobility, open service architecture (OSA).**

I. Introduction

THE Internet protocol version 6 (IPv6) protocol is fundamental to the growth of Internet and has the potential to improve IP functionality and performance [1], [2]. IPv6 supports new Internet applications, and broadens technological development [3]. Corporations such as *Microsoft* and *Nokia* have published white papers on accelerating IPv6 development [4], [5]. Numerous new applications and Operating Systems, including Windows XP and Linux kernel 2.1.8 and higher, already incorporate IPv6 support, but some serious challenges remain in ensuring a successful and smooth transition from Internet protocol version 4 (IPv4) networks. IPv6-based networks have been implemented in isolation, but now the information technology (IT) industry seeks to connect these IPv6 islands across the IPv4 ocean using IPv4/IPv6 translators, and mobile routers (MRs) to support network mobility. When a moving vehicle connects to the Internet to obtain driving information, or an aircraft carries passengers who want to receive their e-mail, mobility mechanisms must be supported. Some studies have been published on Network Mobility (NEMO), including those of the Nautilus6 working group [6] and the IST OverDRiVE project [7]. The Nautilus6 working group is part of the WIDE organization and is managed by volunteers. Nautilus6 has implemented NEMO basic support on NetBSD 1.6.1 with a KAME MIP6. OverDRiVE (spectrum efficient unicast and multicast over dynamic radio networks in vehicular environments) is a research and technology development (RTD) project sponsored by the European Commission as part of the Information Technologies Program (IST). One project working group has specified a MR to provide multiradio access to a moving intravehicular area network (IVAN). Related studies include Connexion by Boeing [8] and InternetCAR in intelligent transportation systems (ITS) [9].

The development of a highly performing all-IPv6 network for information services will soon become an important issue. This work comprehensively reviewed domestic and international projects and trials associated with the development of all-IP networks [10], [11]. The development of high-quality all-IPv6 architecture must fulfill the following requirements.

1) Best-in-class telecommunication and data communication standards.
2) Improvement of existing specifications to yield an open system.
3) Smooth evolution of both networks and applications.
4) Highly reliable and efficient end-to-end QoS support.
5) Support for mobility and seamless handoff between accesses.
6) Separation of service, connection, and mobility control.
7) Rapid and flexible creation of new services

This work concerns the final two points, 6) and 7). An open service architecture (OSA) was constructed to accelerate the integration of telecommunications and data communications, and the ultimate goal is to develop high-quality information applications for the all-IPv6 network [12]. This OSA platform requires the following service characteristics: independence of platform, independence of application, multiple service support, service collaboration support, and support and simplicity of multiple network technology [13].

This paper is organized as follows. Section II introduces background of all-IPv6 network environments. Section III proposes an OSA-based service platform for all-IPv6 network environments of application programming interface (API) developments. Section IV describes the implementation of the service platform, including the IPv4/IPv6 translator based on

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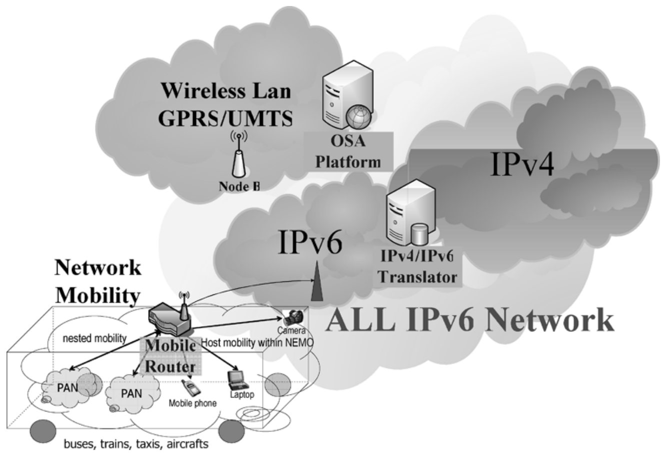

Fig. 1. All-IPv6 network environments.

the network processor and the MR supports network mobility. Section V presents three OSA-based application scenarios and analyzes the performance of OSA-based applications in all-IPv6 network environments. Section VI draws conclusions.

II. All-IPv6 Network Environments

This work integrates the all-IPv6 network environment using an IPv4/IPv6 translator, based on a network processor, and a MR that supports IPv6 network mobility (Fig. 1). Therefore, users with IPv4 or IPv6 network connections, mobile equipments of the PAN or mobile can directly make use of benefits from the OSA-based applications. The following sections introduce IPv4/IPv6 transition and the network mobility.

A. IPv4/IPv6 Transition

The transition between today's IPv4 Internet and the IPv6-based Internet of the future will be a long process, during which both protocols coexist. A mechanism for ensuring smooth, stepwise and independent changeover to IPv6 services is required. Such a mechanism must facilitate the seamless coexistence of IPv4 and IPv6 nodes during the transition period. Internet Engineering Task Force formed the Ngtrans Group to facilitate smooth transitions from IPv4 to IPv6 services. This work employs the IPv4/IPv6 translator mechanisms for all-IPv6 network environments to support applications in OSA.

The fundamental function of translation in IPv4/IPv6 transitioning is to translate IP packets. Numerous of translation mechanisms are based on the SIIT (stateless IP/ICMP translation algorithm) [14]. The SIIT algorithm is applied as the basis of network address translation-protocol translation (NAT-PT) mechanisms. The NAT-PT mechanism is a stateful IPv4/IPv6 translator [15]. NAT-PT nodes are at the boundary between IPv6 and IPv4 networks. Each node maintains a pool of globally routable IPv4 addresses, which are dynamically assigned to IPv6 nodes when sessions are initiated across the IPv6/IPv4 boundary. This arrangement allows native IPv6 nodes and applications to communicate with native IPv4 nodes and applications, and *vice versa*.

The NAT-PT translation architecture, presented in Fig. 2, also includes an application level gateways (ALG). The NAT-PT

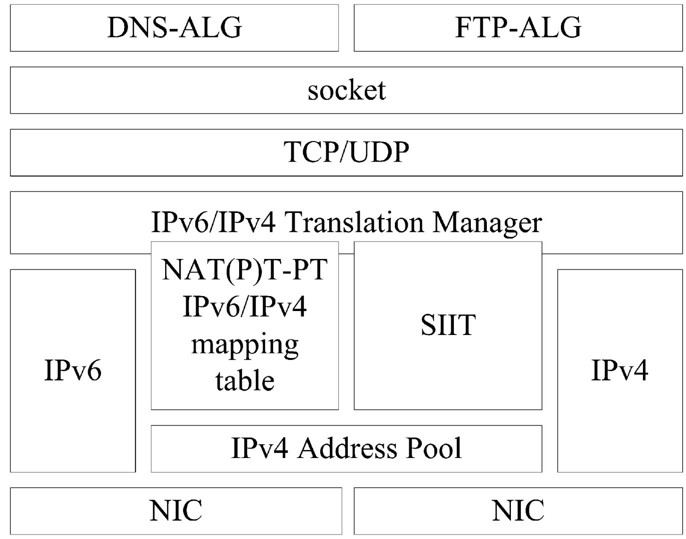

Fig. 2. Basic NAT-PT translation architecture.

mechanism does not snoop payloads, and the application may thus be unaware of it. Therefore, the NAT-PT mechanism depends on ALG agents that enable an IPv6 node to communicate with an IPv4 node and *vice versa*. The NAT-PT mechanism is an interoperability solution that requires no modification or extra software for use with either the IPv4 or the IPv6 network. The mechanism applies the required interoperability functions in a core network, making interoperability between nodes easier to manage and faster to manifest.

B. Network Mobility

The Mobile IPv6 network environment must support the link layer handoff and management mechanism to make network devices mobile. Mobile IP [16], [17] provides the mobility in the IP layer by two-tier addressing. This IP mobility support protocol comprises three functions: agent discovery, address binding update, and tunneling.

A group of nodes that move in a single direction at the same speed in a vehicular area network must be regarded as exhibiting network mobility, [18] as recently defined by the IETF working group, rather than host mobility. All nodes in the mobile network apply a special gateway called a MR, which handles the motion of the mobile network. Three network mobility solutions are HMIPv6 [19], prefix scope binding updates (PSBU) [20], and MRHA tunnel [21]. Each solution has particular strengths, but only the MRHA tunnel method is effective with NEMO. This work applies the MRHA tunnel method to the network architecture.

Hierarchical Mobile IPv6 (HMIPv6): The HMIPv6 protocol does not change the corresponding node's (CN's) operations. Changing these operations requires the incorporation of another network component, the mobile anchor point (MAP), into the protocol. The Mobile IPv6 protocol generates "bing update storms" whenever the mobile nodes (MNs) simultaneously process handoff operations. HMIPv6 represents a solution to this problem.

HMIPv6 utilizes a local home agent as the MAP. When MN moves in to a MAP's coverage area, MN yields the on-link

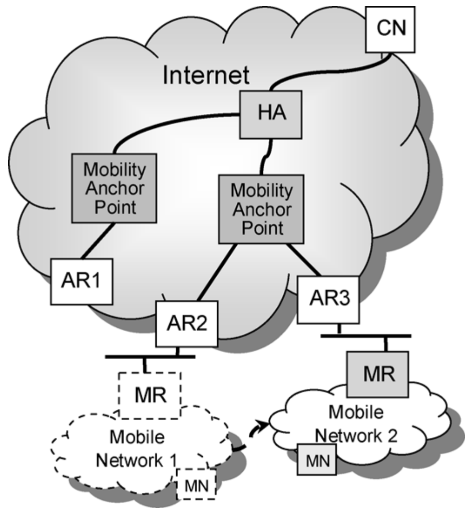

Fig. 3. Hierarchical Mobile IPv6.

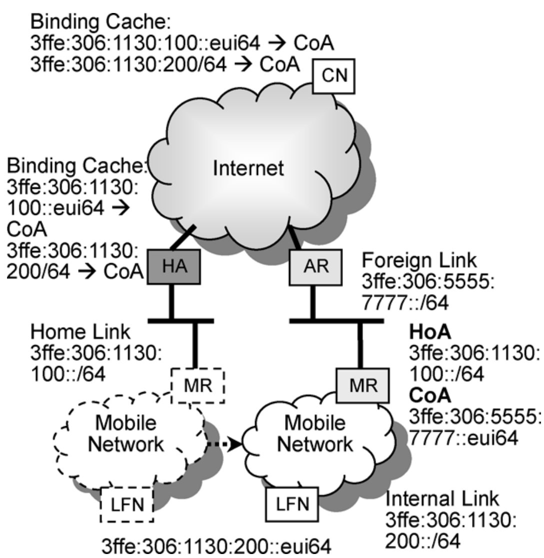

Fig. 4. Prefix scope binding update.

care-of-address (CoA) and sends binding update (BU) messages. When the MAP receives the BU message, it records the BU cache and sends the BU message to the home agent (HA) using the regional CoA of the MAP address. The MAP constructs the tunnel between the MN and the HA. MAP stores the routing information between regional CoA and on-link CoA. The CN sends its packets via the HA to the MAP, which transfers them to the MN in its coverage area. Hence, the MN updates the binding cache only when it moves into a different MAP, as shown in Fig. 3.

Prefix Scope Binding Updates (PSBUs): The PSBU method is also designed to prevent the "binding update storm" (Fig. 4) This protocol extends the traditional BU operations of MIPv6, MRs, HAs and CNs. The PSBU modifies the CoA of one prefix to perform the BU of numerous nodes connected as the mobility network.

The MR is prefixed with CoA when the mobile network moves into another area. It transmits BU messages that contain CoA information to all MNs in the mobile network. The P-bit of the BU message is set to one to state that the BU message is a part of the PSBU mechanism. When the HA receives the BU messages, it checks the P-bit to identify the network prefix suboption field. The prefix information between the mobile network and the MR CoA are added to the biding cache. The CN checks the prefix address of the destination to specify the routers through which data are transmitted.

- MRHA Tunnel

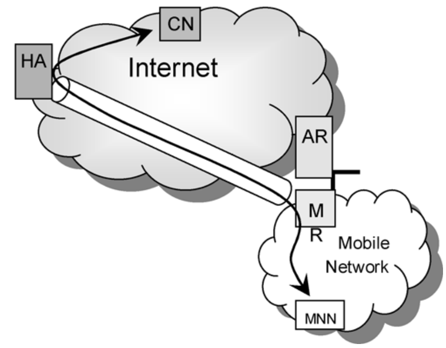

Fig. 5. MRHA tunnel.

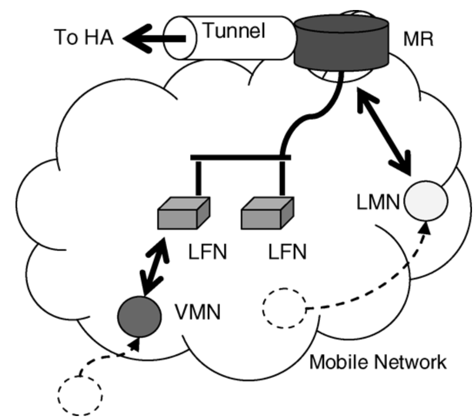

Fig. 6. Nodes within the mobile network.

MRHA Tunnel: Fig. 5 depicts a mobile network that comprises three nodes, which may be fixed (LFN) or mobile (LMN, VMN), according to the classification of the IETF NEMO working group. A local fixed node (LFN) may be a host or a router, and is topologically fixed in relation to the MR, whereas a local mobile node (LMN), whose home link is in the mobile network, can adjust its attachment point in relation to the MR, as can the visiting mobile node (VMN) whose home link is not part of the mobile network.

Applying the MR to handle the movement of mobile network has two particular advantages. Nodes within the mobile network obtain prefixes from the MR. Additionally, the MR of the mobile network connects to external AR and maintains its private MN address. NEMO has three main strengths. First, it involves no direct connection between MN and AR. It also saves power by reducing the radio frequency. Finally, NEMO can support route optimization and the nested NEMO problem displayed in Figs. 6 and 7.