Real-life demonstrations using IPv6 and mobility support mechanisms

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Résumé :

Nous commencerons par décrire dans ce papier les protocoles de communication de prochaine génération qui seront déployés au sein d'Internet dans un avenir proche. Nous traiterons d'IPv6, Mobile IPv6 et NEMO Basic Support, protocoles qui permettront à tout équipement IPv6, qu'il soit en la possession d'une personne ou intégré à une entité en déplacement (véhicule, fauteuil roulant, vélo, etc.) de demeurer connecté à Internet lors des déplacements. Nous expliquerons tout particulièrement en quoi leur utilisation pourra nous être bénéfique par rapport aux protocoles existants. Nous présenterons ensuite les travaux actuels du projet Nautilus6 relatifs aux efforts de validation et de déploiement de ces protocoles, à travers des démonstrations en conditions réelles. Nous décrirons notre plateforme mobile de démonstration et les équipements qui la composent, avec l'exemple E-Bicycle. Nous parlerons aussi des applications grand public qui peuvent être utilisées en environnement mobile, et que nous développons au sein de Nautilus6. Les démonstrations étant un excellent moyen de promouvoir ces nouvelles technologies auprès du public, nous expliquerons plus en détails les évènements passés et à venir mettant en jeu la mobilité IP. Un de nos objectifs est de pouvoir informer le grand public lors d'une démonstration sur le Tour de France 2006.

Abstract :

In this paper, we will first describe the next generation communication protocols that will be deployed in the Internet in the near future. We will discuss about IPv6, Mobile IPv6 and NEMO Basic Support, protocols that will allow any IPv6 device, carried by people or embedded in a moving entity (vehicles, wheelchair, bicycle, etc.) to remain connected to the Internet while on the move. We will especially explain what advantages we can get from their usages compared to the existing protocols. We will then present the actual work done in the Nautilus6 Project about its effort in the validation and deployment of those protocols, through real-life demonstrations. We will describe our mobile demonstration platform and the equipments it is composed of, with E-Bicycle as an example. We will also speak about the end-user application softwares developed in Nautilus6 that can be used in mobile environment. As demonstrations are an excellent way to promote those new technologies to the public, we will explain in details the past and forthcoming events that use the IP mobility. One of our objectives is to inform the general public through a demonstration on the "Tour de France 2006" event.

Introduction

In a few years, wireless technologies have spread in cities with the deployment of hotspots, or at home with wireless routers provided by the Internet Service Providers. Most of the laptops and PDAs are sold today with at least one or two Internet wireless access technologies, such as WiFi or Bluetooth. Combined with the improvements done in the battery's lifetime field, people have gained in freedom and mobility with their equipments.

However, some limitations in the communication protocols prevent the devices carried by people or embedded in a moving entity (vehicles, wheelchair, bicycle, etc) to remain connected to the Internet while moving. One equipment, for instance carried by someone, can be involved in the movement (it is referred as host mobility) as well as one whole network (for instance in a car, it is referred as network mobility). A protocol that would allow those devices to switch transparently between their access technologies, and to move from one network (the one they have at home for example) to another (e.g the one offered at the bus stop in front of their house) while preserving all their ongoing communications is thus necessary.

The IPv6 protocol [IPV6] has been standardized to solve the inefficiencies of the IPv4 Protocol that is currently used for communications between nodes. The Mobile IPv6 protocol was designed to solve the host mobility problem, and has been extended to the NEMO Basic Support protocol to bring a solution for network mobility. Those protocols are already standardized at the IETF [IETF], and are currently being implemented and validated.

Nautilus6 [N6] is an academic project that belongs to the WIDE [WIDE] organization and which is hosted at Keio University [KEIO], Japan. The project is mostly financed by japanese public funds and collaborate with french laboratories such as [ENST-B], [INT], [ULP], and France Telecom R&D. One of the goals of Nautilus6 is to demonstrate that the next generation Internet protocols (IPv6, Mobile IPv6 and NEMO Basic Support) are ready for deployment, through real-life and outdoor demonstrations, and the use of application softwares dedicated to mobility environments.

1. Benefits of IPv6 over IPv4

In today's Internet, most communications between end-to-end nodes are using the IP protocol. This protocol assigns an unique address to all nodes connected to the Internet, and provides the mechanisms to transport data between two nodes.

IP version 4 (known as IPv4) is the current version of this protocol and was the first widely deployed IP protocol. It was standardized 25 years ago. It is now suffering from several design problems and will certainly restrain the creation of new usages of the Internet. The most debated problem with IPv4 is the lack of addresses, but it is by far not the most important.

The need for addresses will increase in the near future. With the voice-over-IP becoming more and more popular, we can guess than billions of people will use an IP phone. Each vehicle will embed tens of IP sensors and some multimedia devices. Obviously, all of those equipments need an IP address. The lack of addresses that can be assigned with IPv4 was solved with the Network Address Translation (NAT) system. However, many peer-to-peer applications (such as video-conference or voice-over-IP softwares) suffer from this mechanism: with NAT, the real address of the host is not directly reachable from its correspondent. The communication cannot be directly established and sometimes need a third part.

We expect more and more equipments will be connected to the Internet, but the IPv4 protocol is not appropriate anymore to distribute and manage the IP addresses. The IPv4 scheme to allocate addresses is not based on any hierarchical scheme and the high fragmentation of address space will lead to an heavy load on backbone equipments (the routers). This is one of the most critical problems with the current IP protocol as it might cause the core routers of the Internet to stop working without prior notice.

Eventually, the IPv4 protocol has a monolithic design that makes it difficult to extend, and contains some mechanisms that prevent new protocols like mobile IP to work flawlessly.

As IPv4 cannot meet the demand anymore, the IPv6 protocol has been standardized in 1998. It can allocate much more addresses and allows to interconnect undecillions (10e36) of nodes at the same time [IPV6-BIG]. Nodes that connect to the Internet can automatically acquire an address thanks to the auto-configuration mechanism. IPv6 also simplifies the use of multicast, that allows many to many (including one to many) communications without wasting the bandwidth. In the multicast communications model, data is sent by the source only once towards a so-called group address. Corresponding nodes wishing to receive the flow only have to subscribe to this group address using specific mechanisms that trigger flow replication in the backbone on the closest router. This way, no duplicate copy of the flow is ever carried within the backbone, as it would be in the current (i.e. unicast) communication model.

Besides those core features, IPv6 also allows the integration of new features such as improved security, quality of service where IPv4 only provides best effort, and mobility mechanisms with Mobile IPv6 and NEMO Basic Support, that we describe in the next section.

The scalability offered by IPv6 will thus allow to interconnect any equipment and to design new services (such as connecting each car to the Internet) and new usages of the Internet (for instance use the vehicle connectivity for monitoring purposes) that we could not imagine with IPv4.

In France, IPv6 is now accessible for research and education [IPV6-RENATER] and some organizations are working on its larger scale deployment [IPV6-TFF]. In Japan [IPV6-JP], some Internet Service Providers have started or are in the process to offer an IPv6 service this year. IPv6 is also a means to collaborations between France and Japan [JSF2003-TE].

2. The mobility protocols

When a node using an Internet wireless access physically moves, it can be at some point of time out of the coverage area of its access network and needs to move to another one. In addition, because distinct operators may operate or the public target is different (pedestrians, cars etc.), usually no single access technology can cover one big area (such as a city). The node thus has to select the best access technology available.

When a node moves from one access network to another or switches between its access technologies, it acquires a new IPv6 address and is not reachable to its previous one anymore. It implies that all current communications (for example streaming video from the Internet) are stopped and later restarted by the user or the application.

The Mobile IPv6 protocol has been defined to address those issues and allow the node to be always reachable at the same IPv6 address whatever the access network it uses. It allows the host to move transparently for the applications and the users, without the need to reset all the current connections each time the host moves to another access network.

Based on the same principles, NEMO Basic Support allows a whole IPv6 network to move from one access network to another transparently for all the nodes inside the moving network. For instance, such a moving network could be a Personal Area Network (PAN) carried by people, composed of a small router that would provide internet access to some devices (such as a PDA, a laptop, or any IPv6-compliant device). A train or a car offering on-board Internet connectivity to its passengers could also form such a moving network.

The Linux operating system now supports both Mobile IPv6 [MIPL2] and NEMO Basic Support [NEPL]. The *BSD operating systems also support both protocols [SHISA]. Nautilus6 has contributed to the NEMO Basic Support implementations on both systems, and uses them on its demonstration platforms.

We invite the reader of the present article to read [JSF2004-RK] in order to learn more about host and network mobility.

3. The real-life demonstrations

In order to demonstrate the applicability of the IPv6 and NEMO Basic Support protocols, the Nautilus6 project has already performed some indoor and outdoor public demonstrations in the past with a PAN-like moving network. Our demonstration platform embeds all the protocols and applications we want to validate [ITST]. We now use E-Bicycle which is a bicycle embedded with a small PAN that is permanently connected to the Internet thanks to the NEMO Basic Support protocol. Although readers may wonder what is the usefulness of a PAN on a bicycle, such a testbed is easy to bring somewhere and to move for demonstration purposes. It is also an ideal platform to improve our energy constraints. Keep in mind that such platform can easily be brought in a car, a train or any moving vehicles, but could also be used for real during a sports event, for tourism, by policemen or firemen in mountains areas etc.

The E-Bicycle demonstration testbed includes the possibility for every one to monitor the bicycle with a monitoring software. It is also possible to speak with the cyclist using voice-over-IP. We also plan to transmit a video stream from the bicycle to the correspondent on the Internet who want to follow the whereabouts of the cyclist. All of this while the biker is riding and moving between different access networks and access technologies.

In the following sections we describe the platform and its usages, and present the application softwares used on it.

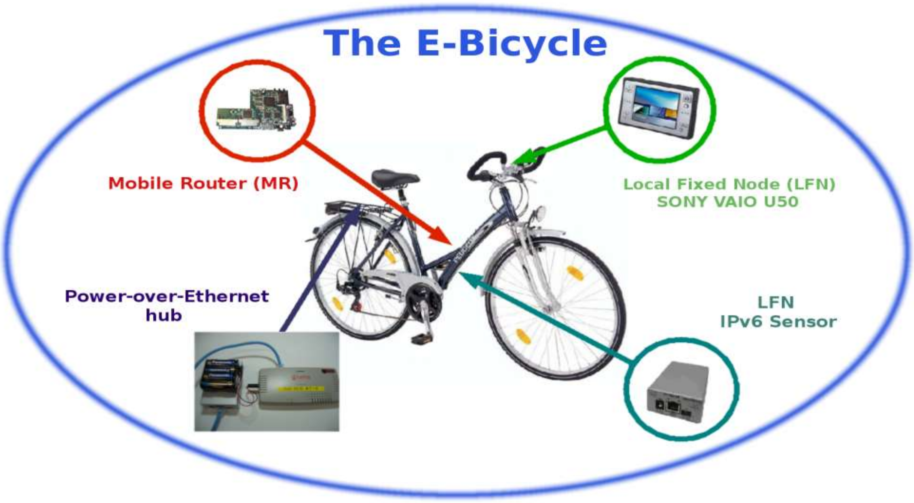
a. The hardware

Our testbed consists in a PAN that can be carried by the end-user and that integrates the protocols described in section 2. It is is composed of:

- A mobile router (MR), which is the gateway between the moving network and the infrastructure. It provides Internet access to all the hosts behind the mobile router. This MR embeds several Internet access technologies, such as Ethernet, WiFi (802.11b), and 3G or 2G cellular card: it is said multihomed. Those 3 technologies allow the MR to get an access to the Internet wherever it is located. NEMO Basic Support is used to provide a permanent access between access points of the same technology (horizontal handoffs) and between access points of distinct technologies (vertical handoffs) while being mobile. The power and weight constraints prompted us to choose a light and low-consuming device: the SOEKRIS single board computer.

- The mobile network nodes (MNN) which are the nodes located behind the mobile router, in the moving network. We chose a Zaurus PDA and some IPv6 sensors. Those small sensors embeds an IPv6 stack and can be reachable to their IPv6 address. They can thus be remotely queried when the MR is connected to the Internet. Those sensors can provide the current temperature, humidity, direction, acceleration and geo-location (GPS coordinates) using the SNMP protocol. We can also bring an IPv6 camera or an usual laptop in this small network.

This PAN is generic and can fit in a bag, a car, or in our previous demonstrations, on a bicycle:

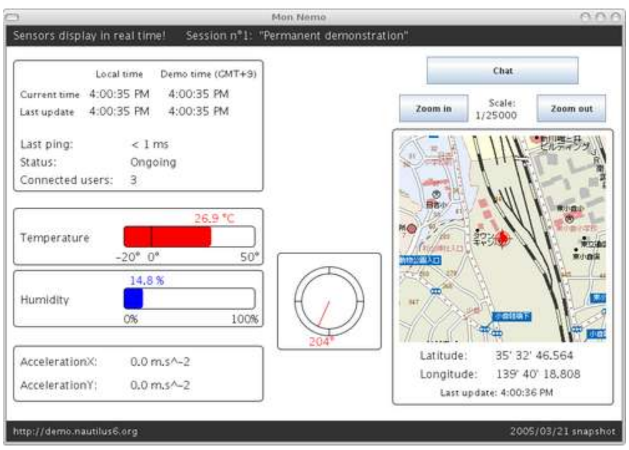


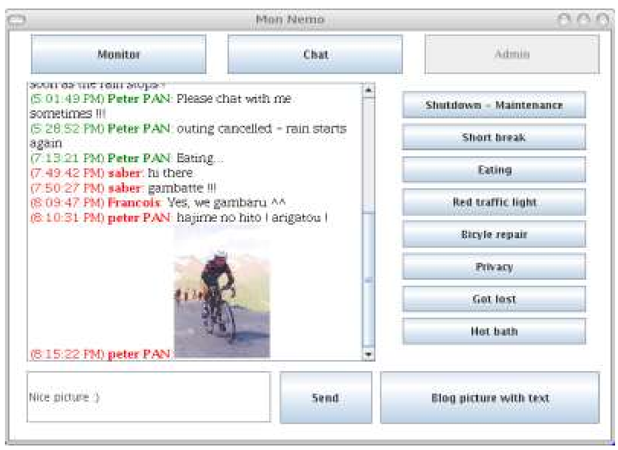
b. The applications

In order to have some attractive demonstrations for the end-user, Nautilus6 has developed several applications to be used in mobile environments. All the applications we describe here are freely available on Nautilus6 website [N6].

We have developed some applications to monitor the PAN from a remote computer:

- MonNemo is a monitoring software for a laptop located inside or outside the PAN. This application displays data provided by the IPv6 sensors that are setup in the PAN. A map is displayed with the current location of the PAN whose coordinates are provided by the GPS sensor. A chat is also available. MonNemo can be setup in the PAN for the user carrying it, but also on any remote PC that would like to follow the whereabouts of the PAN user from its computer. Written in JAVA, it is a modular application that can easily integrate new features.





- ZMS is an application that targets the PDA inside the PAN. It is used to display the sensor information (including coordinates on a map) on a dashboard and natively works on the PDA. However, thanks to the NEMO basic support protocol, it is also able to query positions from a database or even from other PANs wherever they are located. This application can also be run on a regular workstation to localize, track and monitor other moving PANs.

Using Voice-over-IP (VoIP) on E-Bicycle is a good and free solution to keep in touch with the cyclist. As NEMO Basic Support allows to keep the communication ongoing while being mobile, we can imagine to have calls between the cyclist and an Internet user, that may also be himself riding another E-Bicycle. For that purpose we have modified a VoIP phone to support IPv6:

- Kphone/PIv6 is a modified VoIP client. It uses the SIP protocol for signalization, which is a new standard and open protocol used in industry worldwide. The application itself was modified to support both the PDA and the next generation IPv6 at once. It is based on Kphone which is a common linux application and thus retains compatibility with this software.

c. Data gathering and analysis

The information collected during our experiments allows us to sample the inputs and outputs of the live operating mechanisms, as opposed to simulation, which is often used in protocol design. From these data we are able to infer some models about users behavior, efficiency of the protocol, etc. But statistics are also really useful to track protocol misbehaviors, bottlenecks and single points of failure that designers might have missed when thinking about the potential usages.

For all these reasons, we decided to prepare a protocol evaluation environment to be used in Nautilus6 deployments. This environment is made of two parts. A statistics collection server, the central part of the system, collects data from the users of the testbed. The second part is a software tool run on each user's station that constantly monitors chosen parameters and periodically reports them to the central server.

The kind of values that we are monitoring ranges from really generic statistics like the amount of data transferred, to really technical details regarding the wireless communications devices and the protocol mechanisms. Using this large database of events and values, we are able to evaluate the performances of chosen protocols. But this also allows us to know the impact of potential optimizations.

d. Past and forthcoming demonstrations

In march 2005, an E-Bicycle demonstration was performed for the first time, in a 100 kilometers bicycle trip from Shin-Kawasaki to Kamakura (Japan). As the wireless Internet access was not available during the trip, the MR of the PAN was equipped with two cellular cards: 3G, high bandwidth but expensive, and PHS, low bandwidth but cheap. A tunnel mechanism (DTCP) provided the IPv6 connectivity over the cellular access. Upon a failure of an access technology, the Mobile Router could switch automatically to the other available interface. When both access technologies were available, the MR could trigger a switch every 60 seconds on 3G, and 3 minutes on PHS. The experiment has lasted about 4 hours, where 13 correspondents have been connected at the same time to the PAN. From E-Bicycle, the biker could chat with its correspondents, receive some mails, and check his current position with the monitoring software. Each correspondent could get the current GPS position of the cyclist and regular pictures of the surrounding area, send messages to the biker through chat or e-mail, and get some information about the bicycle environment thanks to the IPv6 sensors.

Nautilus6 has now a will to setup a demonstration during the "Tour de France 2006" event to promote the use of IPv6 and mobility. The "Tour de France" is a professional cycling race that lasts three weeks. This event takes place every year and consists in a lap all over around France. As it is the third most important sport event in the world, this would be an excellent place to perform public demonstrations of E-Bicycle and promotion of the IPv6 technologies to the public.

The first stage is a short race that will take place in Strasbourg. If we can get high IPv6 connectivity through wireless LAN on the way, we could improve our E-Bicycle testbed and also allow the public not only to see pictures, but some live video streaming from the PAN using multicast.

The reader can get all relevant information about the demonstrations schedule on Nautilus6 website [N6].

Conclusion

Real-life experimentations are the best way to demonstrate the possible usages of IPv6, personal area networks and NEMO Basic Support. Collecting statistics during real-life testing to evaluate the performance of the system is mandatory to validate those protocols.

In the future, we plan to incrementally improve our test platform with new features that are currently under development. Security and advanced multihoming mechanisms will be integrated for demonstration and validation of the technology. Adaptive applications [JSF2004-FL] will allow to adapt to the network conditions according to some criterions such as bandwidth or price. For example, we can imagine that the PAN user uses some video-conference tools, and that both the video and audio are sent to its correspondent when its PAN is connected to the Internet using WiFi, but that only the audio would be sent when using 3G.

Our demonstration platform is generic enough to be adapted to many other usages. It could be used for health purposes, as we have imagined in the E-Wheelchair testbed [E-WHEEL], or be carried by people in a bag (E-Backpack).

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